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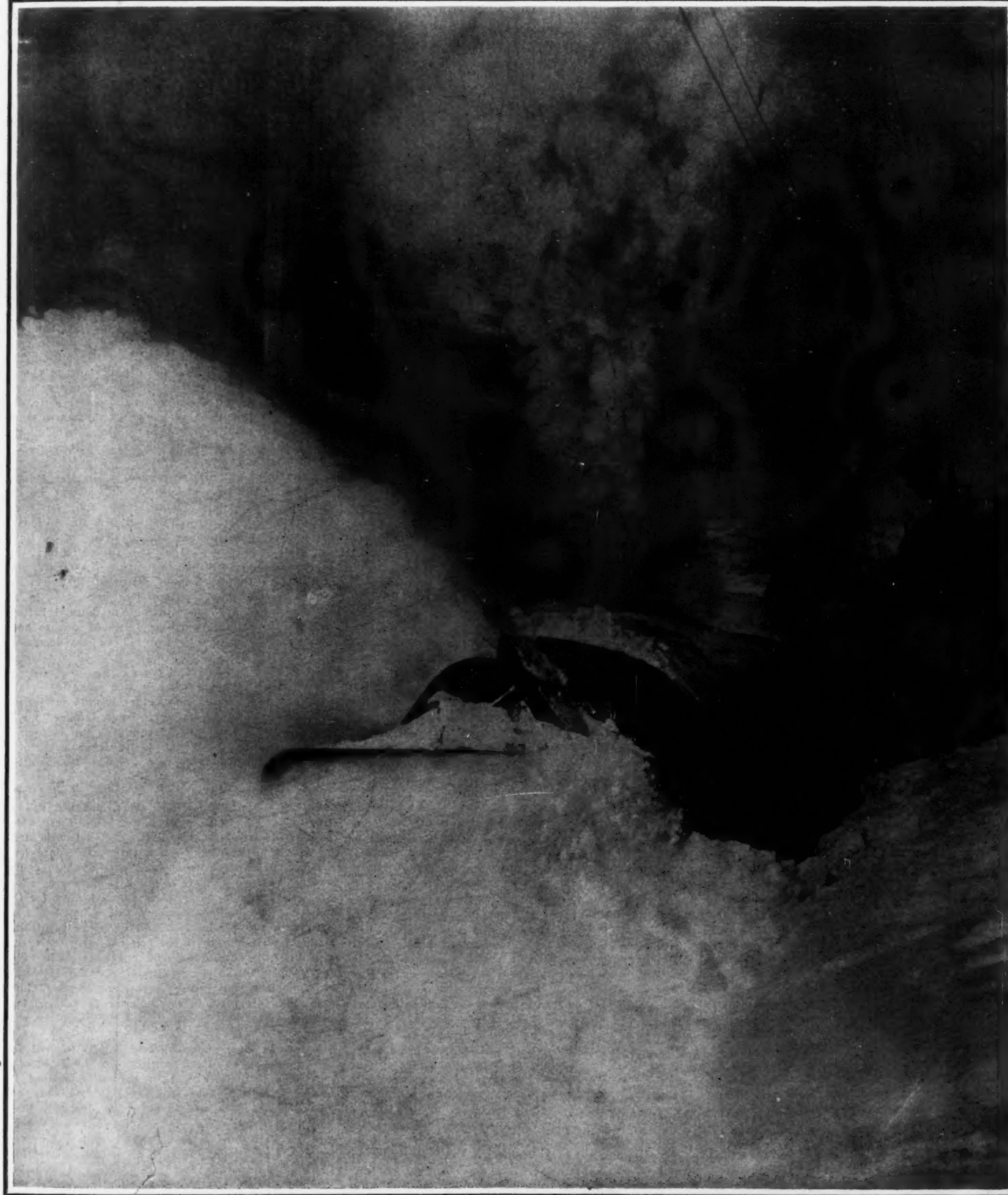


THE ROTARY SNOW-PLOW AT WORK

THE BERGEN-CHRISTIANIA RAILWAY—[See page 88]

Electric Car Lighting*

The Development of a New Branch of Engineering

By D. F. Crawford, General Superintendent of Motive Power of the Pennsylvania Lines

It is not the scope of this paper to go into the history of car lighting and the various elements in connection with the same, but merely to discuss the general proposition, various systems, the recent development of the same, and their applicability to the various conditions to be met.

Electric car lighting, at this date, is comparatively a new branch of engineering; and its development within the past nine or ten years has removed it from the unsatisfactory experimental stage to a real and serviceable proposition. There is still, however, much to be desired in detail development and reduction of costs; in other words, the car lighting proposition is just emerging from its swaddling clothes and is a good, healthy child, which, however, needs considerable care and attention to develop it along the most satisfactory and economical lines.

Electric car lighting is the last step that has been made in the lighting of passenger cars through the chain of candles, kerosene, acetylene, and gas. The reason for its adoption was primarily on account of the danger of fires with gas lighting on the occasion of wrecks. Among the minor reasons for its adoption is the greater ease in controlling the amount of light desired in cars, the elimination of a great percentage of heat, and the furnishing of a light which would not in any way contaminate the air in the car.

METHODS IN VOGUE.

At present there are four methods being developed:

First.—The straight storage with 30 or 60 volts. This consists of storage batteries held under the cars, current from which is distributed through a small panel board to the various circuits.

Second.—The axle generator. This system is simply a straight storage system augmented by a generator driven from the car axle, which by automatic means is thrown across the battery circuit when its voltage is equal or above the batteries, thus charging the car en route, and (theoretically) doing away with the necessity of charging the car at terminals.

Third.—The "head-end" system, in which the prime mover is installed in a baggage car. By this system a current is transmitted through a continuous train line to the various cars. The present voltages in vogue are 60 and 110. With the 60-volt equipment, as a rule, each car is provided with a set of batteries by itself, floating across the line. With the 110-volt system, one or two sets of batteries, as a rule, are installed, preferable one set on the observation and one set in the composite car; that is, as both ends of the train.

Fourth.—The "head-end" system with the prime mover on the locomotive. This system consists primarily of a steam-driven generator mounted on the locomotive and furnishing current at 60 volts through train line, to various cars, each car being equipped with a battery.

METHOD TO BE USED DETERMINED BY CONDITIONS.

As yet, no one of these methods has shown any decided superiority over another, and the whole question is necessarily controlled by the conditions of operation to be met on the various railroads. Where the lighting between charging stations is within 70 or 80 per cent of the capacity of the battery which, within reason, can be carried under the car, and where the time of "lay-over" for the cars, and conditions at a terminal are such that the batteries can be properly charged, it is the writer's opinion that the straight storage system is the most efficient, most economical, and is giving the best results from the standpoint of continuous service. There are, however, conditions where either the lighting load of the car is so great, or the lighting hours of such duration that even with the proper terminal facilities it is impracticable to carry sufficient battery on the car to meet the demand —here we enter the sphere of axle lighting. It is plainly evident, then, that neither the straight storage or the axle light system is capable of meeting any and all conditions of car lighting. There are various railroads that have adopted the axle lighting system as a standard equipment for all cars, including passenger cars with small lighting output; while other roads find it practicable to take care of their coaches by straight storage, and, the dining cars, business cars and postal cars with axle dynamo.

The idea in the essential development of "head-end" system is to do away with both the straight storage and the axle light cars and to furnish current for the lights on all cars in all trains from "head-end" equipment; a battery of medium capacity to be installed on each of the cars, in order to furnish current when engines are being changed, when the train is broken up by switching, and in the event of the failure of the generating unit. It is doubtful if this development will ever be realized, and it leaves for the engineers the choice between the two tangible systems—straight storage or axle device.

THE RECENT DEVELOPMENT OF THE VARIOUS SYSTEMS AND THE ELEMENTS OF THE SAME.

In any system of car lighting, the element of greatest importance and the maintenance of which is rather a large per cent of the total cost, is the storage battery. This branch is of such importance, and its development has been so great that the writer feels justified in taking up some time in going into the history, operation and development.

The first practical storage battery was developed in 1860 in France, by Planté. The essential scheme, as outlined by Plante, in the making of the battery was to take two lead plates, emerge them in sulphuric acid of about 1,200 degrees specific gravity, and charge and discharge them, forming the active material on the lead, peroxide of lead being formed on the positive plate, and spongy lead on the negative plate. This method is carried out to-day by the American manufacturer of storage batteries, with the exception that various chemical means have been resorted to to increase the rate of the formation of the active material. This process is known as a plante formation, and plates made in this manner are known as "plante plates."

A satisfactory theory of the lead sulphuric cell is still to be developed, but I will give you the following simple and generally accepted explanation of its action:

We will consider that we have a glass jar filled with 1,200 degrees sulphuric acid, and emerge in it two pure lead plates. Now, with a voltmeter across these plates, we will find that there is no difference in potential. Now, assume that an electric current is passed through this cell, from one plate to the other, calling the plate to which the positive lead is attached the "positive plate" and the other plate the "negative." This current, we will assume, separates the sulphuric acid H_2SO_4 into two parts, or ions "H" and the radical SO_4. The "H" ions move in the direction of the current or toward the negative plate, and the SO_4 moves against the direction of the current, or toward the positive plate. The hydrogen will be given off as gas bubbles at the negative plate, and the SO_4 radical will unite with the water at the positive plate, forming sulphuric acid H_2SO_4 and liberating oxygen. The oxygen attacks the positive plate, forming a layer of peroxide of lead PbO_2. This process will be kept up until a certain depth of peroxide of lead is formed, then the oxygen will be delivered at the positive plate in the form of gas bubbles, similar to the liberation of hydrogen at the negative plate. Now, if we stop the current, we will find instead of zero potential between the plates that we have a potential of about 2.1 volts, and that the cell is capable of discharging; that is, producing current in an outside circuit, and will give up about 75 per cent of the energy that has been imparted to it. The action in the cell on discharge is opposite to that on charge, and the hydrogen which is liberated at the positive plate will reduce the peroxide PbO_2 to lead oxide which is an unstable combination, and will unite with the free sulphuric acid, forming lead sulphate or $PbSO_4$, while the oxygen delivered at the negative plate will form lead oxide which will unite with the sulphuric acid forming lead sulphate, and, we have the cell in normally discharged condition, or both plates covered with lead sulphate. On again charging the cell, that is, passing current through it from positive to negative from an outside source, the same action will take place as on the original charge, with the exception that at the negative plate the hydrogen instead of being liberated will unite with the lead sulphate $PbSO_4$, forming sulphuric acid and reducing the $PbSO_4$ to metallic lead, which lead, however, is not in its original form, but is in a looser allotropic form, known as spongy lead. We then have the plate in its normal charged condition; the positive plate having a coating of PbO_2, or probably PbO_2, which is of a dark brown color, and the negative plate covered with spongy lead, which is light gray in color. As in the first case, the charge can be continued, the peroxide being formed on the positive plate and the spongy lead on the negative plate, until the action has reached a certain depth, when, as before, hydrogen will begin to be delivered at the negative plate and oxygen at the positive plate, indicating the full charge of the battery.

Now, with a plain lead sheet this action of charge and discharge can be continued with gradually increasing capacity of the element until the active material has reached such a depth that it will mechanically slough off at the same rate at which it is formed. The capacity depends upon the amount of active material, and, as this amount of active material depends upon the surface exposed, the development of the plante plate has been along the lines of increasing the exposed surface of the plate and still maintaining the mechanical strength, and this has been done by the various methods of molding, cutting, or rolling the sheet, so as to form ribs or grid condition, to increase the ratio of the active surface to the projected surface of the plate.

A wide departure from the plante plate was made in 1878 by Faure and Metzger, in Germany, in the invention of what is known as the "Faure" or "pasted plate." Instead of depending upon the electrochemical formation of active material on the surface of the plate, Faure took a sheet of lead and punched it full of holes, or, in some cases the grid is cast, and, the holes or recesses thus formed are pasted full of a mixture of red lead and sulphuric acid. This paste, or litharge, as it is called, in the recesses of the plate forms a hard, cement-like substance, and, when the negatives and the positives are charged, the plates are quickly formed into positives and negatives, the positives turning into lead peroxide and the negatives into spongy lead. It can be readily seen that the pasted plate can be developed into cells having considerable more capacity than the plante plate, and we have the pasted plates in commercial use in connection with automobiles. The pasted plate is better adapted to light rates of charge and discharge, and will not stand up under heavy rates of charge and discharge as the plante plate, due to the contraction and expansion of the active material, which results in the breaking down of the electro-chemical contact of the active material to the supporting grid.

About nine or ten years ago, when the storage batteries began to be used to any extent in car lighting, the battery manufacturer had, for some years, been furnishing storage batteries for stationary service, but, unfortunately, the conditions of car lighting are exceedingly hard on the storage battery, due to the constant vibration, the jolting of the cars, and, further, to the inadequate attention that can be given to the individual batteries and cells in an installation of any magnitude. The normal battery used for car-lighting purposes is a 280 ampere hour cell, where 16 or 32 cells are used per car, dependent upon whether the car is to have 30 or 60 volt lamps. There were three principal types of plates offered:

First—The pasted positives and negative plate, which were not found satisfactory for the service, on account of the active material being loosened up in the supporting grid, and dropping to the bottom of the tanks; the life of the plates being everything but satisfactory, and the resultant cost of operation being high.

Second—The positive plate is composed of a grid about 3/15 inch to ¼ inch thick, punched full of holes about ½ inch in diameter. Into these holes is pressed a button of pure lead. This button is made by rolling in a spiral form a corrugated, pure lead ribbon. In through coach and axle dynamo equipments, this type of plate is found to have very short life, and proved to be entirely unsatisfactory for the service. The manufacturer of this plate has kept pace with the development and to-day is furnishing a plante plate similar to the original, with the exception that the supporting grid has been made twice the former thickness, or, practically the thickness of the button, and present experience seems to indicate that this plate is far superior to the original product and will successfully meet car-lighting conditions.

Third—In the original plante battery offered for car lighting service, the positive plate consisted of a pure lead grid, which had a surface developed by means of passing over it a band saw, sawing out grooves about ¼ inch or 3/16 inch deep, and a little less than 1/16 inch in width. This plate was originally pasted full of active material, which, however, fell out very rapidly, leaving only plante formation. In this condition the life of the plate was good, but the difficulties of developing sufficient surface in this method prevented its succesful use, the surface being insufficient to maintain necessary active material for the capacity desired. The plante plate is now used in both negative and positive plates, the surface de-

* The Yale Scientific Monthly.

veloped by either spinning out the lead in fine ribs, by means of revolving gang knives, or by cutting and turning up the fine ribs by means of shaper knives, the ribs being from 24 to 30 per inch and about 3/16 inch in depth.

The plante plate was the first plate developed to successfully meet the car lighting conditions, it being capable of maintaining its capacity for a big percentage of its life, and being sufficiently rugged to withstand the vibration and hard knocks met with in car lighting.

Recently a number of plates have been put upon the market which the manufacturer expects to meet the conditions; and, notably among them is a cast plante form positive plate, the plate being about 7/16 inch thick and having cast through it is a series of slots less than 1/16 inch in width and about ½ inch long. To date, this plate shows indications of being satisfactory for car lighting service. Another type of plate recently put on the market is a cast grid and grill pate, the grid being cast with openings about three inches square made of lead antimony; and a pure lead grill similar to the positive plate mentioned above being burnt into these openings, with sufficient allowance being made for contraction and expansion. This plate is rather new, and it is hard to say what the results of development along this line will bring forth. The above types are most used in car lighting work; but there are, however, numerous plates of unique design placed on the market from time to time, and for which great claims have been made, but which to date have not met their guarantee sufficiently to make them competitors with the plates to win service.

The recent development of the Tungsten lamp for car lighting purposes, and the development of the serviceable ampere hour meter may make it possible for car lighting engineers to go back to the pasted battery for the reason that:

First.—The Tungsten lamp reduces the rate of discharge on a given car to about half the rate with carbon lamps; and the ampere hour meter installed with 100 per cent shunt for discharge and 80 per cent shunt for charge, makes it possible for the electricians at terminals to give batteries the proper charge, tapering charge at completion and cutting off charge without abusing the batteries by heavy overcharge with the resultant gasing and high temperature. Some of the railroads are making trials of the equipment as above mentioned, but time only will tell whether or not they will be successful. If the refinements in car lighting will allow the use of pasted batteries, it will be advantageous, both on account of the fact that the pasted batteries can be purchased for less money than the present car lighting types and are 25 to 30 per cent lighter.

In regard to the Tungsten lamp itself, there is no question but that this type of lamp will replace carbon lamps. Its success is mainly due to the development of the so-called hot circuit, this being the method whereby, instead of turning the current completely off from the lamp when lights are not required, the lamp is merely switched from the main batteries to one or two hot circuit cells, merely sufficient current being sent through the lamps to make the filament show faint red at night. This arrangement prevents excessive breakage of Tungsten filament, which is an unfortunate characteristic of the filament when it is cold.

One of the greatest developments in car lighting work has been the containing jar. The first batteries were installed in hard rubber jars with loose covers. The jars were rather expensive and in shifting cars there was a continual breakage. Further, the slop of the acid was disastrous to the trays holding the rubber jars and the battery boxes supporting the batteries; also, the corroding of the terminals was excessive. To do away with this trouble, wooden tanks with 4-pound lead lining were developed and installed with loose covers. This development proved to be very discouraging. The slop of the acid rotted the tanks, and the lead linings proceeded to develop sulphated spots between the wood and lead lining, eventually terminating in pin holes, through which the acid was lost. The experience along this line was very expensive to the railroads adopting it. However, the advocates of the lead lining continued developments along this line, and the first improvement was to cover the top of the tank with a full rubber gasket, and secure it with a wooden cover holding it in place with iron straps, it being assumed that the rubber gasket pressed between the top of the lead lining and the wooden cover would sufficiently prevent slopping of acid and corrosion of terminals. This modification was an improvement, but the question of leaky tanks continued, and the railroad people had all they could do to keep their equipment in service.

From this stage, through a series of rapid developments, the present two-compartment lead lined tank was developed, which has proven entirely satisfactory. The outside of lead tanks themselves is cleaned and covered with a coating of petrolyte; the inside of the wooden compartments is painted with acid-proof paint, and before installing the lead linings sufficient molten paraffine is poured into the wooden trap so that when the lead lining is put to place, the paraffine runs up between the lead lining and the wooden compartment, completely filling this space. The covers are now made of hard rubber, the terminals projecting up through bushings of soft, spongy rubber, the covers being provided with sealing grooves to seal them with sealing compound to the lining. This equipment is now standard on a number of roads, and is proving to be entirely satisfactory, although, in engineering work, there is probably nothing that is not subject to further improvement.

DEVELOPMENT OF THE AXLE GENERATOR.

In the installation of an axle generator on a car, the engineer is met with conditions which make it anything but smooth sailing. He has to drive the dynamo from an axle which does not have any constant relation to any part of the car. The lateral displacement of an axle in the truck itself is about ¾ inch; the vertical displacement about 2 inches. Further, the trucks are pivoted, and can swing out of line with a car going around curves to a considerable extent. Some of the first developments contemplated flexible positive drives through gears from the axle, and the installation of a generator armature on the axle itself. These did not meet with any great approval by the railroads; first, on account of the fact that the car axles have to be changed, due to the wearing of the tread and the flanges, and second, the location of the machine made it rather inaccessible for inspection.

These difficulties resulted in the development of what is known as the "outside suspension," which scheme, with few exceptions, is universally used. The dynamo, in this case, is hung outside of the truck, from bails, or in a "cradle," and the belt is run from the generator pulley to a pulley mounted on the rough axle. Belts, however, have a limited life, and, the losing of a belt en route, as a rule, means failure of the lights on the car, or, in most events, of at least dim lights in service. Recently, a number of chain manufacturers have been offering chain drives for this service, and it is hoped by the railroad people operating lighting systems that these chains will meet with success. However, it is too early to offer any opinion on the same. The conditions of the driving axle with varying relation to the dynamo, and the fact that it is absolutely impracticable to lubricate the chain, puts the chain manufacturer up against a difficult proposition.

The dynamo itself is not the joy of an ideal life; the variations of track alignment and surface, and the swinging of trucks around curves make it a hard proposition to maintain the lubrication of armature bearings, and keep the oil from fields, armature windings, commutators and brushes. The machine is necessarily, devoid of any means of ventilation, as dust and dirt of the right-of-way must be prevented from getting into it. The dynamo is used for charging batteries and lighting car, and is driven by a variable speed axle, and is liable to run in both directions; therefore, the control of this apparatus has been subject to numerous arrangements and patents. To provide for the generating of current in one direction (the machine revolving in both directions), a pole changer is almost universally used. This practically consists of two types; first, the brushes themselves are fastened to a movable brush ring, and the friction of the brush revolves it in one direction, or the other, dependent upon the movement of the car, so as to produce current in the proper direction; and, second, a worm and cam arrangement, which is in operation for the first few turns of the dynamo and changes the leads through means of a pole changer switch.

The provisions for varying speed of the machine can be made in two ways: First, voltage regulating scheme, whereby the voltage is maintained constant. This would be the preferred arrangement, but to date, all attempts along this line have utilized instruments of such delicate construction that they have been unserviceable. Second, the universal scheme adopted is that of constant current. One of the first steps along this line with installation of a dynamo on the bottom of a car was the dynamo being so hung that it could be moved towards or away from the driving axle, and the varying speed of the car axle was taken care of by slippage of the belt. This scheme worked out satisfactorily, but practically could not be maintained. The present and most universally used system is the arrangement of maintaining a constant current out-put from a generator by controlling the current flowing through the field. One of the pioneers in this line used an ordinary rheostat, two toothed wheels being mounted on the rheostat handle, a dog engaging each one of them, one dog to turn resistance into the rheostat and one to turn it out. These dogs were made to revolve through a small arc by means of a constant running motor, their contact with the respective wheels being made by means of a current solenoid. This scheme, for some time, was the only equipment in service. But in the development other schemes have been devised which are equally serviceable and have considerably less wearing parts and less liability of disarrangement. Among them is the immediate improvement of the above device, in which motors, dogs and cog were omitted and the controlling solenoid operates directly on the rheostat arm, which swings up and down over the resistance contacts. The other scheme is to provide a certain pile resistance in the field, and the current solenoid brings varying pressure on a carbon pile, depending upon the current, and allowing more or less field excitation. A rapid departure is made from the above equipments in a recent installation wherein all rheostats and regulators were omitted and the regulation is obtained by a counter E. M. F. armature mounted on the main generator armature. This counter E. M. F. machine, when the car starts up, acts as an exciter, its field being obtained from the battery current or in a constant direction. Now, as the car picks up in one direction or the other, the current in the counter E. M. F. machine will be in one direction or the other, and reverse the direction of rotation of the main armature and the direction of its field excitation maintains a constant polarity. As the machine picks up in speed the main contact closing the circuit of the batteries is closed and at the same time a little polarizing switch is installed whereby the excitation of the main generator is thrown across its own brushes as a shunt machine, either in one direction or the other, dependent upon the directions of rotation, and the counter E. M. F. machine is thrown in series with the current to the main fields and in opposite direction, therefore, when the car picks up speed the generator is prevented from increasing its current and voltage from the fact that the counter E. M. F. machine also increases its voltage and cuts down the current going through the fields.

In addition to the above arrangements there have been installed methods whereby machines can be set at constant current output and made to increase this output in proportion to the lighting lead, thereby lighting the lamps directly, and maintaining a constant charge to the batteries. Developments have also been made recently along the line of cut-out switches, so arranged that the machine can be cut down and battery charge ceases when the batteries have reached a predetermined voltage.

The axle dynamo appeals to the car lighting engineer, and, in the writer's opinion, if the equipment can be developed to meet the conditions and operate cheaper than the straight storage system, they will be universally installed. The ideal condition would be to install axle dynamos and batteries on cars, so that they could run from one shopping to another, with very little, if any, attention; that is, about 18 months, and the regulation so perfected that no matter whether the car is in runs where very little lighting is required, or in runs of continual night and lighting service; that the condition would be properly matched.

The event of the Tungsten lamp and the possible use of pasted batteries will tend to change some of the old theories in connection with axle dynamos. The contention of the axle dynamo manufacturer has been that the installation of an axle dynamo allows the user to run his cars on 3 instead of 60 volts, thereby doing away with the initial cost in the maintenance of half a set of batteries, the reduced cost of the present battery and the possible use of the still cheaper pasted type of battery, leaves very little, if any, argument in the above contention. The plan of the car lighting engineers and axle generator people should be the development of a small sized machine, which can be wound for either 30 or 60 volts, with the same mechanical parts. The 30-volt machine with 16 cells of batteries should be used on cars where the lighting needed is not over 15 amperes at 30 volts. On the cars with greater lighting capacity the same machine wound for 60 volts should be used with 32 cells of batteries. The above mentioned 60-volt equipment, in view of the greater cost of the 30-volt machine to meet the greater lighting requirements, will be as economical in operation as the 30-volt equipment, but, on the other hand, will have more standby capacity with less lighting failures. In the meantime the safest course of the car lighting engineer is to operate the straight storage system, until such a time that the axle dynamo is properly developed to meet the conditions.

Incense Powder.—Benzoin 250 parts, cascarilla 250 parts, musk 1 part, sandal-wood 500 parts, saltpeter 100 parts, vetiver root 150 parts, frankincense 500 parts, cinnamon 150 parts. Dissolve the saltpeter in water, soak the other, pulverized, ingredients with the solution, dry the mass and re-pulverize it. This powder, spread on a surface and moderately heated, on an iron stove-lid for instance, takes fire spontaneously and smoulders completely away.

The Manufacture and Industrial Application of Ozone*

The Possibilities of a Remarkable Gas

By Dr. Oscar Linder

SINCE the discovery of ozone in 1840 by Schoenbein it has been a fascinating subject for investigation to many chemists and physicists. The vast commercial possibilities of ozone have been conceived by many scientists, and it is interesting to note the prophecy of Berthelot that ozone had an immense future and would ultimately work a veritable revolution in the chemical industry. The scientific literature and the records of the Patent Office will bear proof of the attention which has been paid to this remarkable gas by scientists throughout the world. There have been more than one hundred patents issued by the United States Patent Office on methods and apparatus for producing ozone, and the number of foreign patents is legion. It is true that most of them are based on the original method of producing ozone by subjecting air to electrical stresses, and most of the claims are but special arrangements and combination embodying this fundamental principle, or means for producing the electrical stress. However, there are some notable exceptions, such as for example, methods of producing ozone by means of heat or ultra-violet rays, although the efficiency of these processes at the present time is too low to enable them to compete successfully with the electrical method.

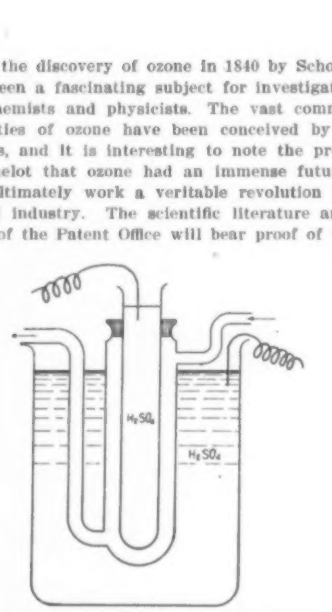


FIG. 1.—BERTHELOT OZONIZER

PROPERTIES AND OCCURRENCE.

Every chemist and most laymen know that ozone is a gas with the composition O_3, and it is an allotropic modification of oxygen, formed from the latter by an endothermic process. According to Berthelot, 29,600 calories are required to form 1 gramme-molecule of ozone from oxygen. Expressed in a popular way, ozone may be called oxygen in a highly energized form. As a gas it occurs, or can be produced, in greatly diluted form, but it can be condensed to a deep blue liquid of a specific gravity of 1.46, which boils at —106 deg. C. (—159 deg. F.) according to some investigators, and at —125 deg. C. (—191 deg. F.) according to other investigators. It is very unstable in either form, and upon standing, decomposes slowly, if greatly diluted, and may do so explosively if in liquid form.

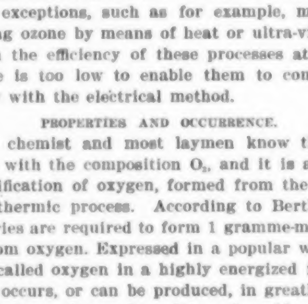


FIG. 2.—RELATIVE PRODUCTION OF OZONE AT DIFFERENT TEMPERATURES AS COMPARED WITH 22 DEG. C. (71.6 DEG. F.)

This decomposition increases with a rising temperature and at a temperature above 270 deg. C. (518 deg. F.) ozone cannot exist. Its density as a gas is 1.66, air being 1.

Ozone has a characteristic odor which is perceptible even when in extreme dilutions with air. So delicate is our sense of smell to this gas that it is easily possible to detect the presence of one part ozone, in about ten million parts air, which would correspond to a concentration of 1/100,000 of 1 per cent. It is the most powerful oxidizing agent known, and will attack, even when greatly diluted, all oxidizable substances, especially organic matter. It is, therefore, a valuable oxidizing agent, not only because of the ease of its application as a gas, but also because no other elements are introduced into the reaction but oxygen.

Ozone occurs in nature in the atmosphere and is supposed to be formed in small quantities through electric conditions of the atmosphere, and by the action of ultra-violet sun rays upon the atmospheric air. The latter formation explains why it is more abundant in the higher regions where the ultra-violet rays are largely absorbed by the atmosphere. The quantities in which ozone is present in the atmosphere is largely a matter of conjecture. It has been given as from 0.1 to 12 parts in 1,000,000 parts by volume of air, but most likely it is present, even where most abundant, in quantities of not more than 1 in 1,000,000. We are not going much wrong if we assume it to be about 1 part in 1,000,000 parts air 1/10,000 of 1 per cent, or a little less than 1 milligramme per cubic meter air). The very fact that even in smaller concentrations than this its presence can be detected distinctly by our sense of smell, while its detection by chemical means is, at best, uncertain, must be taken as an indication of its importance.

MANUFACTURE.

Ozone can be made in a number of different ways, but the only method of commercial importance at the present time is its formation through electric stresses. I might mention that a process of great interest and of commercial possibilities is the formation of ozone through the action of ultra-violet rays upon air, these rays being produced by means of a mercury vapor lamp inclosed in a quartz tube. Another method of scientific interest is the production of ozone by means of heat in which Nernst and Clement obtained fair yields (as much as 3½ grams of ozone per kilowatt hour) by leading oxygen over incandescent bodies and cooling it immediately by liquid air. F. Fischer obtained equally good results by blowing air at a velocity of 50 meters per second through a slit 1 millimeter wide over a Nernst burner and then cooling it in a glass tube surrounded by water. However, at the present time these methods are too inefficient for commercial purposes.

The apparatus designed by Berthelot, a sketch of which is given in Fig. 1, is the prototype of most ozonizers which are on the market at the present time. Occasionally parallel plates are used in place of concentric tubes, but in general there is very little difference between the different designs and makes except as to construction.

There may be either one or two layers of a dielectric material, which is usually glass, free from lead, or mica separating two metal electrodes. The latter are used mostly in the form of alluminium or tin foil pasted to the dielectric or sometimes solid metal or metal brushes, which may or may not touch the dielectric. The thickness of the dielectric layer is usually in the neighborhood of 3/32 inch and that of the air space about ⅛ inch, but these dimensions depend of course, largely on the character of the electric energy. When the metal electrodes are connected to the opposite terminals of an alternating current of suitable frequency and voltage, a so-called cold or silent discharge, free from sparks, takes place through the glass and is visible by a faint violet glow distributed evenly through the air space between the electrodes. The air or oxygen to be ozonized is passed through this glow and is thereby ozonized. It is not definitely known whether it is the stresses themselves which cause the ozonization of the air or whether it is due to the ultra-violet rays which are generated in the air gap, but the latter theory seems more probable at the present time. It should be mentioned here that the use of oxygen instead of air, while giving considerably higher yields and concentrations, has been generally abandoned on account of the costliness of the oxygen. A step-up transformer of high ratio and comparatively low current capacity constructed on the principle of potential transformer is always a part of an ozonizer except in cases where induction coils or static machines furnish the electrical energy.

In order to understand the action of an ozonizer, it is necessary to first dwell upon the influence of voltage, heat and moisture on the generation of this gas and upon the relationship between yield and concentration.

The amount of ozone which can be generated in an ozonizer of the Berthelot type is theoretically in direct proportion to the voltage of the discharge per unit of air ozonized. This would be true in practice if it were not for the destructive action of heat on ozone. There is a considerable amount of heat formed in the so-called cold or silent discharge, and the heat thus generated increases of course, as the square of the current of the discharge. In using a high wattage of electric discharge per unit of air ozonized, a condition which is necessary in order to obtain the high yields and concentrations required for industrial purposes, it is desirable, therefore, to use as high a voltage and as low a current as feasible. Most failures in ozone generators are due to insufficient understanding of this principle, the natural

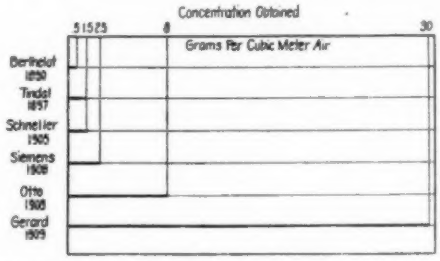


FIG. 3.—INCREASE IN 20 YEARS IN CONCENTRATION OF OZONIZED AIR

tendency of designers being to use as low a potential as possible. There is no good reason for employing low voltages and it is now proven that, contrary to former belief, the formation of ozone is not limited to certain voltages or frequencies. It is only at about 8,000 to 10,000 volts that the process of ozonization becomes economical and apparatus employing voltage below that are hopelessly low in efficiency for all purposes where both high yields and concentrations are required. In former years, limited knowledge of high potential transformers and other alternating current machinery made it necessary to use low voltages, but at the present time the design and manufacture of small and efficient apparatus of this kind affords no difficulties, and there is, therefore, no necessity of restricting the voltage employed. Voltages as high as 40,000 volts are now used, and the most successful ozonizers are those which employ high voltages.

The effect of heat on the formation of ozone is illustrated in the diagram shown in Fig. 2, which is taken from L. Gerard's treatise on ozone in the August number of the Proceedings of the Societe Belge d' Electricians, 1909, from which you can see that the production rapidly diminishes as the temperature increases. After 80 deg. C. (177 deg. F.) it falls off still more rapidly and at 270 deg. C. (518 deg. F.) it is 0. The importance of keeping the electrodes as well as the air to be treated cool can readily be grasped from this diagram.

The very best designed ozonizers still generate a sufficient amount of heat so that for commercial yields and concentrations it becomes necessary to resort to

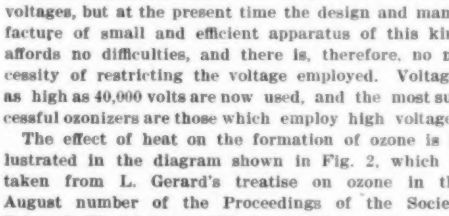


FIG. 4.—INCREASE IN 20 YEARS IN THE YIELD OF AN OZONIZER

artificial cooling of the electrodes or of the air to be ozonized. Some designers have even resorted to refrigeration of the air before ozonization, and some very good results have been obtained thus, but it should be said that refrigeration is not necessary in small apparatus, if sufficiently high voltages are used, although for low voltage discharges it is perhaps the only means of obtaining anywhere near commercial yields.

The concentration of ozonized air is the amount of ozone expressed in grams contained in one cubic meter air, and is a very important factor in all processes in which ozone is used. The yield of an ozonizer is usually expressed by giving the amount of ozone generated in grams per kilowatt hour electric energy consumed. The latter includes the transformer losses,

* A paper presented before the American Institute of Chemical Engineers at the meeting held June 24th, 1910, at Niagara Falls, N. Y.

but no other auxiliary apparatus. Much progress has been made during the last 20 years in both concentrations and yields obtained, as shown in Figs. 3 and 4, which are taken from Gerard's above noted treatise. You will notice that concentrations as high as 30 grammes per cubic meter air, which would correspond to two per cent by volume, and yields as high as 100 grammes per kilowatt hour have been obtained. Very recently even higher yields have been achieved in an experimental plant built on the Steynis refrigerating system, which is reported to have given never less than 105 grammes and sometimes as high as 250 grammes of ozone per kilowatt hour at a concentration of about 4 grammes.

Unfortunately an ozonizer is, in its action, similar to a storage battery, and it is at the present time impossible to obtain the highest concentration at the greatest efficiency, and an increase in the concentration will bring with it a decrease in the yield or *vice versa*. This is easily understood when the heating effect of the discharge is considered. In running an ozonizer at a high concentration the wattage of the electrical discharge per unit of air to be ozonized must be high and this necessitates a slow rate of flow of the air to be ozonized or a high density of discharge per unit of electrode surface. Both these conditions favor excessive heating of the air during ozonization, and this we have seen is unfavorable to a large yield. On the other hand, in running an ozonizer at a high yield, the most effective cooling of the electrodes is necessary and can be best obtained by circulating through the electric glow a large volume of air, resulting, of course, in lowered concentration (see Fig. 5). It is evident that this relation between concentration and yield, being due to the heating effect of the discharge, will be all the more favorable from a commercial standpoint, the higher the voltage employed.

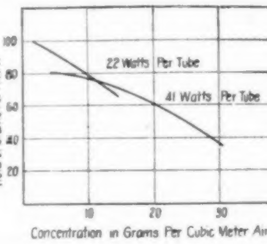


FIG. 5.—RELATION BETWEEN YIELD AND CONCENTRATION OF GERARD OZONIZER.

The density and discharge per unit electrode surface is a factor depending largely on the design of the apparatus and on the voltage and rate of flow of the air through the apparatus. As a general rule it is considered good practice not to exceed 0.4 watt per square centimeter, electrode surface.

The effect of humidity of the atmosphere on the production of ozone is shown in Fig. 6. The presence, in the air to be ozonized, of water vapor so greatly reduces the production of ozone that for all commercial concentrations except for ventilation it is necessary to dry the air before ozonizing it. This practice is followed in almost all instances and is usually accomplished by passing the air through a tank containing lime before passing it through the ozonizer, or, in large plants, by refrigeration.

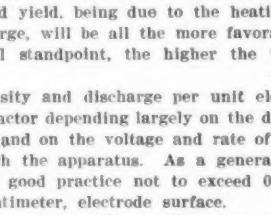


FIG. 6.—RELATIVE PRODUCTION OF OZONE AS A FUNCTION OF HUMIDITY.

It must be understood that where very low concentrations only are required, such as for ventilating cooling and drying of the air. In a well designed apparatus of this kind sufficient cooling is accomplished preferably by the artificial circulation of the air set up and the reduced production of ozone in the presence of such water vapor can be taken care of by making the apparatus adjustable.

In subjecting air or oxygen to the effect of electric stresses, it is well known that some other products are formed besides ozone. If water vapor is present in the air or oxygen, there may be some hydrogen peroxide formed. However, the drying of the air before ozonization does away with this possibility. In small ozonizers used for ventilating purposes in which it is not customary to dry the air, the amount of hydrogen peroxide formed is so small and the dilution so great that its presence can be disregarded, especially considering the great similarity in action between hydrogen peroxide and ozone.

Besides hydrogen peroxide there is always formed a more or less small amount of the oxides of nitrogen. Their presence in the ozonized air is highly undesirable and should be carefully avoided. The formation of these oxides is favored by heat, sparks, dust and dirt, and it is therefore important in the construction of ozonizers not only to provide sufficient cooling but also to prevent the formation of disruptive discharges or sparks in place of the cold or silent discharge during the operation of the apparatus. The formation of sparks is favored by the accumulation of dust and dirt in the air space, therefore in the design of ozonizers it is very important that particular attention be paid to the necessity of keeping the air space clean and free from accumulation of dust and dirt. The amount of nitrous oxides formed is, as a rule, very small. In well designed ozonizers there should not be more than one or two per cent of nitrous oxides formed, figured on the amount of ozone generated. In poorly designed apparatus the amount of nitrous oxides formed may run up to five or ten times this amount.

During ozonization the air to be treated must be kept in positive motion; a fan, blower, or air pump is therefore a necessary accessory of every well designed ozonizer.

In regard to the quantitative determination of ozone it should be said that most of the figures which we find in the literature up to about ten years ago are unreliable, owing to defective methods. At the present time the determination of ozone in the higher concentration does not afford any difficulties, but in low concentrations, such as in the atmospheric air, accurate determinations are even now impossible. For industrial use the method now considered standard is the absorption of ozone by means of a neutral potassium iodide solution. The iodine set free by the ozone is titrated, after acidifying, in the regular way by means of sodium thiosulphate and starch. The hydrogen peroxide which may be found in the presence of vapor in the air to be ozonized is best eliminated by passing the ozonized air over finely divided chromic acid crystals before passing it through potassium iodide solution. For very small concentrations, manganese chloride paper in conjunction with Quajak tincture or Thallium suboxide as recommended by Engler and Wild and also the well known tetra-base paper are giving fair comparative results. They are not, however, accurate enough for determining quantitatively the amount of ozone in the atmospheric air.

It is not the intention of this paper to go into details as regards various apparatus for producing ozone, as there are a number of treatises available where this information can be obtained. For example, the book on ozone by Henry Lecoux, the paper on ozone by Leon Gerard in the August number of the Proceedings of the Societé d'Electricians, 1909, the various papers by Ehrlwein, F. Fischer, Warburg, and many others, some of which I mention in this paper. Most plants where a large amount of ozone is consumed have been designed specially to suit the conditions of one particular problem. Therefore there is no such thing as standardization in this line, and the number of designs so far is nearly as great as the number of installations.

The first ozonizer constructed to meet with some success was that of Berthelot in 1899, a sketch of which is given in Fig. 1. The general principle of this apparatus has not been changed to any great extent by later investigators, although changes in details of construction and the progress in our knowledge of alternating current machinery made it possible for later designers to greatly increase its efficiency.

The best known of the ozonizers of recent date, working on the Berthelot principle, is that designed by the engineers of the Siemens & Halske Co., whose comprehensive investigations and publications have done much to bring the subject to the attention of the technical world. A still more recent design and and which has achieved considerable success is that of Gerard, a sketch of which is given in Fig. 7.

INDUSTRIAL APPLICATION.

The industrial application of ozone has been delayed greatly in the past by unusual requirements set up by the manufacturers of such apparatus in regard to the nature of the electric current supply. Until comparatively recently it was necessary to use static machines or induction coils run by primary batteries in order to obtain a discharge of the characteristics recommended by the manufacturers, and even today the use of interrupted direct current or of alternating current of frequencies not met with in practice are prescribed for some apparatus. It is no wonder that under such conditions the use of ozonizers has made slow progress, but fortunately it has been found that the regular alternating current of commercial frequencies can be used just as well, and in most cases to better advantage, than many special forms of electrical energy recommended in the past. Thus it is now possible to purchase ozonizers operating from alternating lighting circuits without further electrical apparatus than a transformer; in places where direct current only is available we can convert it into an alternating current of the desired frequency by means of a small and inexpensive converter, several types of which are now on the market for that purpose. Small ozonizers for ventilating purposes are even made so complete and compact that they can be connected to any electric light socket by means of a screw plug and cord, and they can be obtained for any commercial voltage, either alternating or direct current.

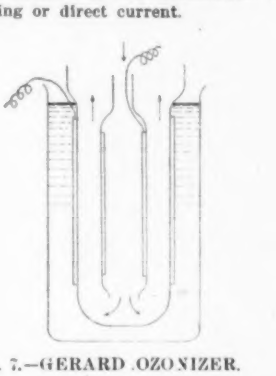


FIG. 7.—GERARD OZONIZER.

Water Purification.—The subject of water purification by means of ozone has been so extensively treated and discussed in the past that it is not necessary to go into details. The success of this method of water purification has been definitely proven and it has been found that in large installations it is not only much safer and more effective, but also cheaper than quartz filtration, and requires much less space. Large installations for water purification are as a rule designed specially to suit the requirements of one particular problem, therefore the subject can not well be treated generally with other uses of ozone.

The bactericidal properties of ozone, since having been studied and proven by Froehlich and Chimuller, have perhaps been more frequently investigated than any other of its properties, and the fact that bacteriologists like Pasteur, Roux, and Koch have endorsed them has left no further doubt in the minds of the most skeptical persons. Ozone oxidizes the impurities in water and renders them harmless; it clears dirty water and still leaves no compounds harmful to the health or disagreeable to the taste. This purification is accompanied by a distinct phosphorescence of the water. In cases where muddy appearance is largely due to substances of mineral origin, it is customary to partially clear the water by means of a pressure filter before ozonization. At different times it is customary to use about twice as much ozone as is found necessary to thoroughly purify an average sample of the water in the laboratory. The concentrations used for water purification are high and range from 5 to 12 grams of ozone per cubic meter (35.3 cubic feet) of air, according to the quality of water. The amount of ozone required for purifying one cubic meter of water also varies greatly according to the quality of the water, but may be given as from 0.5 gramme to 10 grammes ozone per cubic meter of water. The above figures represent about the limits ever used for purifying water of any kind.

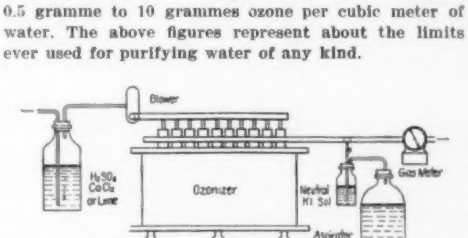


FIG. 8.—APPARATUS FOR USE IN THE APPLICATION OF OZONE

Owing to the low solubility of ozone in water (it is given as from 5 to 10 parts in 1,000 parts water), a very intimate contact between ozonized air and water is necessary, and this is usually accomplished in towers constructed on the principle of the absorbing tower or by sprays and injectors.

There seems to be no close agreement between the figures published about the cost of operation of the water purifying plants now in operation, but a perusal of the data available would show the cost of purifying, including interest, depreciation and maintenance, as being from 0.1 to 0.4 cent per cubic meter or from $3.80 to $15 per million gallons, according to the quality of the water to be purified.

Ventilation.—One of the newest fields for the application of ozone is in the ventilation of rooms and buildings. Good ventilation is being appreciated more and more because of the physical comfort which

it affords as well as because of its therapeutic and hygienic importance. In all modern buildings, theaters, passenger boats, hotels etc., a ventilating system is an important part of the equipment, and even in places the very name of which is associated with bad air, such as street cars, sleeping cars, tunnels, etc., the feasibility of supplying good air is being seriously studied. Up to the present time the problems of ventilation have mostly been categorically solved by heating or cooling the air to the proper temperature, and in some few cases by filtering it through a sheet of water or a solid filter. Recently, however, the demand has arisen to improve the air by charging it with ozone to a concentration corresponding to the normal percentage found in places noted for the purity and freshness of the atmosphere.

It has been found and demonstrated that the presence of ozone in air in small quantities has a beneficial physiological action. It gives it a pleasant and cheerful effect which is not noticed in air free from ozone, it stimulates the appetite and produces sound sleep. Its action has been compared with the effect of moderate physical exercises upon the general condition of body and mind. Physical examinations of people working in places which are supplied with poor air have disclosed a decided gain in weight and chest measure after ozonizing their air supply for some weeks.

Ozone is now considered a necessary constituent of good atmospheric air. It is well known that air in cities and in all well populated places is depleted of or entirely free from ozône, owing to the abundance of ozidizable organic matter in such districts. The absence of such floating matter in the open country and especially in the mountains and on the sea is held accountable for the presence of ozone and for the general healthiness at such places.

The question how to improve the air in cities and in closed places where people congregate is a problem which is just now receiving some serious attention for the reason that by far the largest percentage of deaths among the adults in cities is due to diseases resulting from bad air. Perhaps the greatest destination of ozonizers is in the field of improving general air conditions, for the powerful oxidizing properties of ozone can be put to a particularly practical use for purifying and deodorizing air. Indeed, it has been found that foul gases, organic matter floating in the air, offensive odors and everything else which is commonly called air sewage is thoroughly oxydized and destroyed by ozone. Ozone in high concentration will kill any germ known to science; in concentration for breathing purposes its action is different. It is well known that this matter which we have defined as air sewage is a specially attractive ground for bacteria, miasmata and other animal and plant life of the lowest order, which thrive in cities and congested districts. In such small concentrations as ozone is employed in ventilation its beneficial action is probably its destruction of organic purposes, it is usually unnecessary to employ artificial matter in the air rather than the direct destruction of bacteria, which has sometimes been accredited to it. It has not been proven that ozone, when diluted to the extent of one part in one million parts of air, can act directly as a bactericide, but it is an established fact that even in such dilutions it acts as a deodorizer and destroyer of the food and favorite surroundings of the bacteria, thus depriving them of the conditions favorable to their propagation. So energetic is the action of ozone on such undesirable matter that the presence in the air of ozone can be taken as an indication of the purity of the air.

Ozonizers made specially for ventilating purposes are now on the market and are made either of portable or stationary type. There are several systems manufactured in this country and in Europe, the latest one on the domestic market is made either for alternating or direct current and in various sizes to suit the requirements of the air space to be taken care of, and is portable, self-contained and adjustable. The general plan of these machines is to draw in the air to be ozonized and subject it to electrical stresses by passing it through an air gap in which a silent electric discharge takes place, and then discharge it immediately to the outside air.

The cost of operation of such ozonizers is, as a rule, very low. The consumption of electric current is about 65 watts for circulating and ozonizing 10,000 to 15,000 cubic feet of air per hour. The concentration is, of course, very small and does not greatly exceed that found in the best outdoor atmosphere. It should be mentioned here that a common mistake made in the installation of ozonizers for ventilating purposes is that too high a concentration of ozone for breathing purposes is produced. An excess of ozone in the air is unpleasant to many people and, while it cannot be considered dangerous, still there is a possibility of producing temporary discomfort. The concentration best adapted for breathing purposes has been a subject of much discussion, and it has been variously given as from 0.001 to 0.5 grammes per cubic meter air. For direct breathing a concentration of 0.5 gramme is much too high and would be extremely unpleasant even for only a few minutes. The figure that has been best agreed upon is a concentration just a trifle higher than the natural concentration in the atmospheric air, say about two parts ozone in 1,100,000 parts of air, or about 0.0012 grammes ozone per cubic meter air. A popular instruction for the use of such ozonizers is that there should be enough ozone in the air that its odor is just perceivable at all times. Ozonizers giving higher concentrations than 0.01 gram cannot be considered safe, and in using such apparatus particular pains must be taken to have the concentration properly reduced by diffusion.

While one is inclined to regard these ozonizers skeptically at first, still their benefits in every day life have been proven and demonstrated in many cases by medical authorities. As a general means for improving the air and as a deodorizer, ozonized air has found no rival and is bound to come into very general use. Numerous houses, hotels, schools, theaters, and restaurants, and especially abroad, the leading establishments of this kind have been equipped with them, and the reports on their effectiveness are generally very gratifying.

Miscellaneous Applications.—The industrial applications other than for water purification and ventilation are manifold. What I have said about manufacture, ventilation, and water purification will give you a fair idea of the possibilities along different lines, and I have perhaps treated these two applications at greater length than their relation to chemical engineering demands.

For reasons previously explained the use of ozone as an oxidizing agent in purely chemical industries has not yet been recognized to any great extent. Since however, it has been possible to obtain concentrations up to 30 grammes of ozone per cubic meter of air, which corresponds to two per cent of volume by means of a comparatively simple apparatus many possibilities present themselves of using ozonized air for oxidization process, especially in cases where it is desirable that no foreign element be introduced into the reaction.

By virtue of its gaseous condition and its powerful oxidizing qualities, ozone is an ideal gas for sterilizing and disinfecting purposes. Like all strong oxidizers, ozone is destructive to animal and vegetable life of the lowest order, while to animals of higher order and to human beings it is comparatively harmless. There are several installations that are being experimented with in order to test the efficiency of ozone as a disinfectant, one being, for example, at the quarantine station at New York and another one at the Pittsburgh Homeopathic Hospital. Judging from the results obtained in sterilizing rooms, bandages, laundry and surgical instruments in hospitals, it is believed that ozone will ultimately supplant formaldehyde in disinfecting rooms and buildings. The concentration used for disinfecting and sterilizing purposes is, of course, rather high and should not be less than 5 grams and preferably as high as 10 grams per cubic meter air. The sterilization of sewage is a problem which we will be confronted with in the near future in order to avoid the increasing pollution of our rivers and lakes and will be a very fruitful subject for ozone some day and one in which it will have to show its full worth. Very considerable concentrations are required for this purpose and 10 to 20 grammes per cubic meter air will be none too high.

The uses of ozonized air in medicine are many, but it is not within the scope of this paper to discuss them. Let it be mentioned that it has been used successfully for inhalation in cases of anemia, nervousness, insomnia, and pulmonary diseases, or for local application in the treatment of skin diseases, cancerous growths, in obstetrics, etc.

One of the largest fields for ozone in the future is the preservation of food products. Experiments have shown that milk, cream, and butter can be completely sterilized and therefore kept from fermentation and souring for a considerable period of time; eggs, when stored in an atmosphere of ozonized air, will keep for months without apparent change; the effect on fruit is still more striking, as ozone prevents the molding, which starts on the outside of the skin. In storing meat products it has been found that refrigeration is greatly helped if the air in the storage rooms is ozonized, and that the temperature of the refrigerating room or chamber can be considerably higher in the presence of ozonized air than under ordinary conditions. As a preservative, ozone is also destined to meet with considerable use, supplanting drugs, sugar, and sterilization by heat.

The apparatus necessary in the applications of ozone is very simple. It is illustrated in Fig. 8 and consists of the drying bottle or tank, containing sulphuric acid, calcium chloride, or lime; the fan, blower, or air pump necessary to circulate the air through the ozonizer and the ozonizer proper, containing the step-up transformer. For experimental purposes it is usual to have a rough testing outfit in connection with the apparatus, consisting of an absorbing bottle for the potassium iodide solution, an aspirator to draw in from the main tube and measure the volume of air passing through the absorbing solution, and a gas meter in the main line, by means of which the total volume of air ozonized can be measured.

Considerable success has been achieved by the use of ozonized air in order to prevent the growth of parasites, as, for example, in the storage of flour and flour products, to prevent molding. It has also been applied in many cases, especially in England and Belgium, to the fermenting cellars of breweries, where it prevents the growth of parasites and still has no retarding effect on the fermenting process. The number of living bacteria in those cellars is said to be thereby aso greatly reduced, and it is generally found that those which are not directly killed are not capable of reproduction.

Concentration of about 0.5 gramme ozone per cubic meter air is usually adapted for this purpose. Besides this, a number of breweries have adopted the ozone system for the purification of their water.

In the case of the manufacture of wines and liquors ozone is being used to a large extent in France for the purpose of destroying the empyreumatical odor and oxidizing the fusel oils in products which have not been sufficiently aged. The action of ozone in this case is said to be identical to the action of aging and it is reported that wines and liquors are produced in France in from three to twelve months which cannot be distinguished from similar products which have been aging for from two to ten years. Ozonized air is also largely used for sterilizing casks and other implements used by producers of wines and liquors.

The bleaching and deodorizing properties of ozone have been recognized early, and are now being utilized to a considerable extent in the case of fats, greases, and oils of mineral, vegetable, and animal origin. Vegetable oils, for example, are not only bleached and discolored, but also thickened, and in the case of animal products, like tallow, grease and fats, ozone has been found a valuable means of improving appearance and quality. Rancid and other offensive odors can be entirely removed, and it is possible in this way to considerably reduce the amount of waste.

In the case of sugars, as well as flour and starch, ozonized air has been found to accomplish bleaching very satisfactorily. Its bleaching effect is superior to even that of chlorine and is all the more striking, as it not only bleaches but destroys diseased parts and kills parasites which feed upon such products. There are hundreds of other applications of ozone in bleaching, such as, for example, delicate processes like bleaching of ostrich feathers and fine fabrics. In ordinary laundry work ozone surpasses the effect of bleaching chemicals and has the additional advantage of sterilizing the fabrics without injuring the strength and flexibility of the fiber, such as the bleaching agents generally used for this purpose do. The bleaching of wood pulp is also one of the future fields for ozone. As to the concentration of ozonized air which is employed for bleaching, it is evident that it should be as high as possible, and an average of 8 grammes per cubic meter air is none too high.

There are a number of purely chemical uses for ozone, and it is safe to predict that as an oxidizing agent it will come into much more general use in chemical manufacturing and research work than it is at present. As an example I call attention to the use of ozone in the production of artificial camphor, in the synthesis of rubber, and the large field it will have in the future in the manufacture of perfumes.

The metallurgical industry has started to make quite an extensive use of ozone in the cyanide process of extracting gold, and it is claimed that the yield has been increased from 60 per cent to over 90 per cent by means of ozonized air.

A field for ozone which has not as yet been exploited, but which is bound to become important in the future, is the sterilization of the water for refrigeration. Ice made from water which has previously been purified with ozone is perfectly clear and sterile, and will ultimately fill a long felt want in this direction.

As a deodorizer there is no substance which can anywhere equal ozone, and it is possible by means of it to remove in an incredibly short time offensive odors in storage rooms, glue and leather factories, and in other establishments noted for their disagreeable odors.

The outline which I have given here of the accomplishments and possibilities in this new field should serve the purpose of calling attention to and awakening an interest in a remarkable product which for general usefulness is surpassed by very few of the thousands of substances known to chemistry. There is no special branch of the chemical industry where ozone cannot in some manner or other fill a want, and I believe that there are few, if any, members of this Institute present who will not find it to the interest of the industry they represent to further investigate the subject.

The Generation of Power*

The Enormous Development of the Energy Stored by Nature

By D. S. Jacobus, E.D.

No art has developed within the last few years at a more rapid pace than that of the generation of power. This development has been in the line both of an enormous increase in the amount of power produced and in the economy with which it is generated. With this have come developments in the electrical field, and so closely are the two related that the unit of measurement of efficiency of our power plants is usually expressed electrically, that is, in the cost required to generate one kilowatt of electrical energy per hour, or the amount of fuel, or its equivalent heat value, required to generate a kilowatt hour.

The great advance in artificial illumination brought about by the electric light, the establishment and extension of trolley lines for city and interurban service and the distribution of power to both small and large consumers, have heavily taxed the resources of our central power plants, which have been continually increased in capacity to meet the demands. So rapid has been the advance that what was the best practice but a few years ago is in most cases not the best practice of to-day, and it is no rare occurrence to see equipments which were up to date less than ten years ago replaced by something better. The development of the steam turbine has had much to do with this—a development which has proceeded so rapidly that it must be regarded as one of the marvels of engineering.

Steam is to-day the ruling power. Hand in hand with steam come the gas-engine and hydraulic-power developments. Each has its own particular field, and any individual case must be considered by itself before it is possible to say which form of power will be the most economical. Of these three methods of generating power the hydraulic surely has the advantage as far as the conservation of our natural resources is concerned, but history has shown that the development of most water powers is simply a preliminary step to the installation of an auxiliary steam plant to insure continuity of service, and in many cases the power demands become such that the steam plant is eventually the more important of the two. What follows will bear more especially on the production of power by steam.

We often hear the cry that we are a wasteful people and that we should save our coal deposits and make more use of such natural powers as the wind and the waves. These methods of producing power, especially in the case of the wind, have filled particular needs, but as a means of generating the large quantities of power now used for industrial purposes they would be completely inadequate. For example, let us consider the power generated by a single steam turbine of 20,000 kilowatts' capacity. To produce this power with windmills each having wheels 25 feet in diameter and with a wind velocity of 20 miles per hour, we would need over 6,000 windmills, and if the mills were placed 50 feet apart they would form a line about 60 miles long.

Again, let us compare the power obtained from the steam turbine with that available from a wave motor. If we should construct a wave motor which would convert half of the total energy contained in the waves into electrical current and which would be operated by a continuous series of waves 200 feet long and 4 feet high, it would have to extend along the coast for a distance of about a mile and a third to give as much power as the single steam turbine. The cumbersomeness and cost of constructing such a wave motor would render it impracticable, whereas for certain uses where smaller amounts of power are needed a wave motor might be developed to serve the purpose.

Let us consider animal power. A horse develops, say, three-quarters of a steam-engine horse-power under favorable conditions, which means that about 35,000 horses would be required to do the work of the single 20,000-kilowatt steam turbine.

The consideration of the subject from a theoretical standpoint is most interesting. The steam engine is handicapped in its efficiency as compared with the gas engine by the lower initial temperature of the working fluid in the cylinder, whereas the gas engine is handicapped as compared with the steam engine by not being able to make use of a low temperature at the end of the cycle. In a steam engine a great part of the work is done by the steam at a pressure below the atmosphere, every degree that the condensing water is lowered being available for increasing the work and representing the lower limit of temperature. The steam turbine is especially adaptable for utilizing the low temperature at the end of the cycle. In a gas engine the lower limit of temperature is that of the hot gases at the end of expansion, a temperature usually higher than the initial temperature of the working fluid in a steam engine.

The question is often asked why a good arrangement could not be obtained by combining a low-pressure steam turbine and a gas engine so as to secure the benefits of the high initial temperature in the gas engine and the low final temperature in the steam engine. On working out an actual example, however, it will be found that the work of the steam turbine would be comparatively small, amounting to less than 10 per cent of that of the gas engine, so that the installation of the steam turbine would not as a rule increase the capacity or efficiency enough to warrant the additional expense and complication of the plant.

Many so-called new cycles for the production of power have been brought out from time to time. In most cases these cycles serve as an illustration of the old adage, that a little knowledge is a dangerous thing. The inventors often work out pages of thermodynamic formulæ to uphold their views. In other cases the problem is dealt with in broad generalities, heat units being handled as if they were packages that could be moved at will from shelf to shelf and so made to pass from one part of the apparatus to the other without loss, no consideration being given to the amount of surface required to effect the transmission or to the radiation losses. In some cases heat is assumed to be transferred from one part of the cycle to the other, no proof being offered that the interchange will be possible, that is, from a hotter to a colder medium. Still other inventors actually build machines only to find that this is the most expensive way of becoming convinced that they are mistaken. I have had to examine many such schemes and in most cases it could be readily shown that the cycle was at variance with the well-known laws. Cycles that do not conflict with the laws can usually be shown to be impracticable when the sizes of the parts necessary for an actual machine are computed and the radiation losses allowed for. If we could but find a way of disposing of heat at a temperature lower than that of the surrounding objects, we could utilize all of the heat of the ocean or the atmosphere to develop power. Many of the schemes advanced in the so-called new cycles are equivalent to this and the inventors have wasted their energies in striving for the impossible.

Much depends on the load curve of a power plant in obtaining economy. If a continuous uniform load could be carried, many of the vexing problems which confront the power plant engineer would be eliminated. It is difficult to carry economically enough reserve capacity to meet the daily peaks in the load. Then again, there are exceptional peaks which occur only at rare intervals, so that a considerable percentage of the available power may be developed only for a few hours every month, or for that matter, for a few hours every year. Modern practice leads more and more to developing higher ratings from boilers during such intervals, and a boiler should be used which, under proper operating conditions, may be driven to a capacity that is limited only by the amount of coal which can be burned in the furnace. Again, it is desirable to use boilers that may be cut into the line quickly either from banked fires or starting from a cold state.

The practice in this respect is exemplified by considering the installations of the Commonwealth Edison Company at Chicago, where the first 5,000-kilowatt turbines erected in this country were installed. This was in 1903, and eight boilers each having about 5,000 square feet of heating surface were supplied for running a turbine. The maximum rating for these turbines was 7,500 kilowatts. Later on 12,000-kilowatt maximum-rating turbines were installed, each with eight boilers of the same size as provided for the 5,000-kilowatt machines. Still later, machines of 14,000-kilowatt maximum were run with the same size and number of boilers as the original machines of 7,500-kilowatt maximum.

The steam pressure in power plants of this country is usually about 185 pounds to 200 pounds per square inch and about 150 deg. of superheat is carried. The economy of superheat in this work is well established and represents the best practice.

The steam turbine is becoming more and more the standard for large power-plant work, both on account of its fuel economy and the low cost of attendance. The most economical fuel consumption under operating conditions that has so far been published was obtained in a test with piston engines where a kilowatt hour was turned out of the station for each 25,000 B.t.u. contained in the fuel. The station referred to is the Redondo plant of the Pacific Light and Power Company of California, and the results of the test, at which I was fortunate enough to be present, were given by the designer of the plant in a paper published in the Transactions of the American Society of Mechanical Engineers for 1908. The fuel was California crude oil. The load curve had two high peaks and the entire plant was shut down during a lay-over period of four and a half hours per day. The 25,000 B.t.u. represent the heat of combustion of the oil used per kilowatt hour net electrical output for the entire fifteen-day period during which the test was run. It is a fact worthy of note that this result approaches that to be expected for the plant economy of large gas engines for the class of service considered where the power is variable and reductions must necessarily be made for all the auxiliaries, etc.

While no results for plant economy as good as the above have been published for steam turbines, it is only fair to say that the figures for steam consumption for turbines show that better than this economy can be obtained under uniform load conditions. When it comes to plant economy, so much depends on the load conditions that it is hard to compare one plant directly with another.

We have in this country many large power plants. In New York we have the Edison Waterside stations and the Interborough station; in Boston the Boston Edison Company's station, and in Chicago the Commonwealth Edison Company's stations, two of which, built near each other, at Fisk and at Quarry Streets, have an aggregate maximum capacity of over 200,000 kilowatts. It is noteworthy that the first 5,000-kilowatt turbines installed in this country, which have already been referred to, were placed in the Fisk Street station about seven years ago. The rapid development in the art is exemplified by the fact that these turbines are now replaced by others, although at the time they were installed they represented the latest advance in power-plant practice.

The growth in the consumption of power has been so enormous that the question is often asked, Where will it stop? What is a luxury to-day becomes a necessity to-morrow. Where our grandfathers used the tallow dip and oil lamps we must now have a flood of light rivaling that of the sun itself. Our streets are illuminated in a way that our forefathers would have considered impossible, and no one would wish to go back to the darkness that would tempt the highwayman and render travel difficult. Ventilating fans are now regarded as a necessity and electrical current is used for a number of household purposes. We could not indeed go back to the old days without giving up many comforts. But where will this great increase in the demands on nature's coal pile land us? This we will have to leave to others to answer. Let us stop for a moment, however, and compare what we are doing with that great silent source of heat and power—sunshine. The sun shining on the world for a single minute imparts as much heat as that contained in all the coal and oil produced in our country in a year, and when we make this comparison we cannot help but appreciate the littleness of our endeavors and have confidence in the great recuperating powers of nature.

* The Journal of the Franklin Institute.

Economy in Meat Production

At a recent meeting of the French Agricultural Society a paper was read by Messrs. Gouin and Audouard, discussing the influence of the age at which cattle are slaughtered upon the production of meat. It has been stated by some that the present scarcity of meat in France is due to the method in vogue of slaughtering animals before they have reached complete development. The authors consider that this is an error, and that stock should be utilized as soon as the flesh has attained its value as meat for the table, this being to the advantage both of producer and consumer. The total amount of hay fed to three animals up to the age of 3½ years is 33 long tons. This would suffice for seven animals up to the end of the second year. But the yield in meat from the seven young animals is 40 per cent in excess of that from the three adults. Thus with the same amount of food material the stock raiser can put much larger quantities of meat on the market by rapidly renewing his stock.

The Bergen-Christiania Railway

A Recently Completed Scandinavian Line

By the English Correspondent of the Scientific American

One of the most important railway enterprises which has been completed in Europe within recent years is the trunk standard-gage line that has been recently opened across the Scandinavian peninsula for the purpose of providing direct communication between Bergen, on the Atlantic seaboard, with Christiania. The necessity for such a link has been sorely experienced for many years past, but the engineering difficulties confronting the scheme were of such a stupendous character as to prevent its earlier realization.

The line was first projected in 1870, and was estimated to be about 320 miles in length. It was realized from the first that construction would be difficult, inasmuch as the mountains to be negotiated rise very abruptly from the sea, and the interior plateau is storm-swept throughout the whole year. However, two engineers were selected to ascertain its feasibility. Their report was of such a favorable nature as to induce the authorities to sanction the first part of the scheme, which entailed the building of a meter-gage line from the sea to Vossangen at the foot of the mountain range, a distance of about 67½ miles. The work was commenced forthwith, and was opened for traffic in 1883.

The extension of the line eastward was not abandoned, but the main difficulty was to find an easy passage through the mountains. This was a difficult matter, as the range is so broken up. The engineers made several preliminary surveys and elaborated several routes, but in any case extensive tunneling would be requisite. These preparations occupied eleven years, and it was not until 1894 that the actual extension was sanctioned. Even then the authorities only decided to proceed as far as Taugevandet, 114 miles from Bergen, leaving the further extension open for the time being.

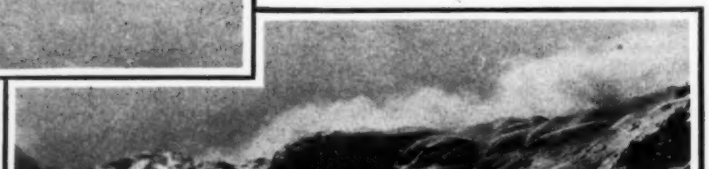
The engineers pointed out that owing to the range dropping so precipitously into the sea, with an absence of wide valleys, the line would have to rise to a great altitude to secure a favorable grade. They also emphasized the fact that owing to the exposed nature of the interior table land, rain and snow would also remain a serious problem. The snow in particular was a sore question; and to gather reliable data concerning its fall, drift, and so forth, several meteorological stations were set up in 1884 and daily observations made. These revealed a rather remarkable state of affairs, it being found that snow fell every month during the year, and that the average fall during the winter was 11 feet deep. Its movement was also extraordinary owing to the severity of the winds, which caught the soft dry snow and piled it into drifts, which formed as much as 16½ feet deep. Even in the month of August, in the sheltered places, drifts were found over 2,000 feet in length by 5 feet deep.

These observations sufficed to demonstrate that constructional work would be arduous and difficult, and also that extreme precautions would have to be observed to keep the line open and to mitigate the evil consequences of the drifting movement by means of extensive defenses in the form of wooden screens. In all, nine routes were drawn up and submitted to Parliament. The outstanding feature of these routes was the means of penetrating the range from the coast side. A tunnel could not be avoided, and the most feasible route was one involving the boring of twelve tunnels aggregating 11¼ miles in length in the total distance of 47½ miles through the range from Voss to the summit of Taugevandet. The most formidable was the Gravehals tunnel, 17,420 feet in length. The steep grades and sharp curves which were necessary to preserve alignment were also vital factors.

The government, however, accepted the Gravehals tunnel route. After leaving Voss the line commences its ascent of the range immediately, rising from 150 feet above sea level to the Taugevandet summit at 4,250 feet. The Gravehals tunnel, which is the longest work of its kind in northern Europe, has its western entrance at about 95½ miles from Bergen, at an elevation of 2,818 feet above sea level. From the Bergen portal the tunnel has a grade of 5 per cent for some distance, followed by a stretch of 3 per cent to its highest point, where there is a dead level stretch 590 feet long, followed by first a 3 per cent, and then a 5 per cent downward grade to the eastern portal, the drop continuing until Myrdalen, approximately 100 miles from Bergen, where 2,839 feet altitude is reached.

Owing to the timber line in this district being at 2,460 feet altitude, so that the tunnel portals are fully exposed to wind and weather, its construction was an exacting task. Boring was carried out from both ends, the contract price being $808,000 complete. For the supply of electric energy the Kjos Fall was harnessed and the current transmitted to the two ends of the tunnel, the aggregate of the water turbines on the west end being 280 horse-power. On this side two Brandt boring machines working at an average pressure of 80 atmospheres were used, together with four Frölich and Klüpfel pneumatic boring machines, as the former system could not be used for the full section. On the eastern side hand boring was resorted to. The estimated rate of progress was 197 feet per month on the west and 50 feet per month on the east side, respectively. The results of the first year's working, however, were so far below the estimated progress, owing to the extreme hardness of the rock, that the contractors had to improve their methods in order to be able to keep to the contracted time for completion. Accordingly, on the east side hand boring was first superseded by electric boring machines driven by a small petroleum motor, but being unsatisfactory were discarded in favor of pneumatic appliances, with which such advance was made that the two headings met two months before the contract time. The tunnel, however, was not completed for nearly two years later, which delay, however, exercised no significance, inasmuch as the adjoining sections of track were behind, owing to the scarcity of labor.

This latter factor proved a difficult problem. The works were far from civilization, and owing to the exposed position of the site, the privations were so severe that men refused to be attracted to the spot, especially as they could secure plenty of work at the same wages in more congenial centers. The conditions under which the tunnel was driven were certainly unique. Once work had to be suspended for some six weeks owing to an avalance crashing into the power house on the west side, and carrying half of it away. On another occasion a stoppage of two months' duration became imperative, as no water was obtainable, while the extreme severity of the



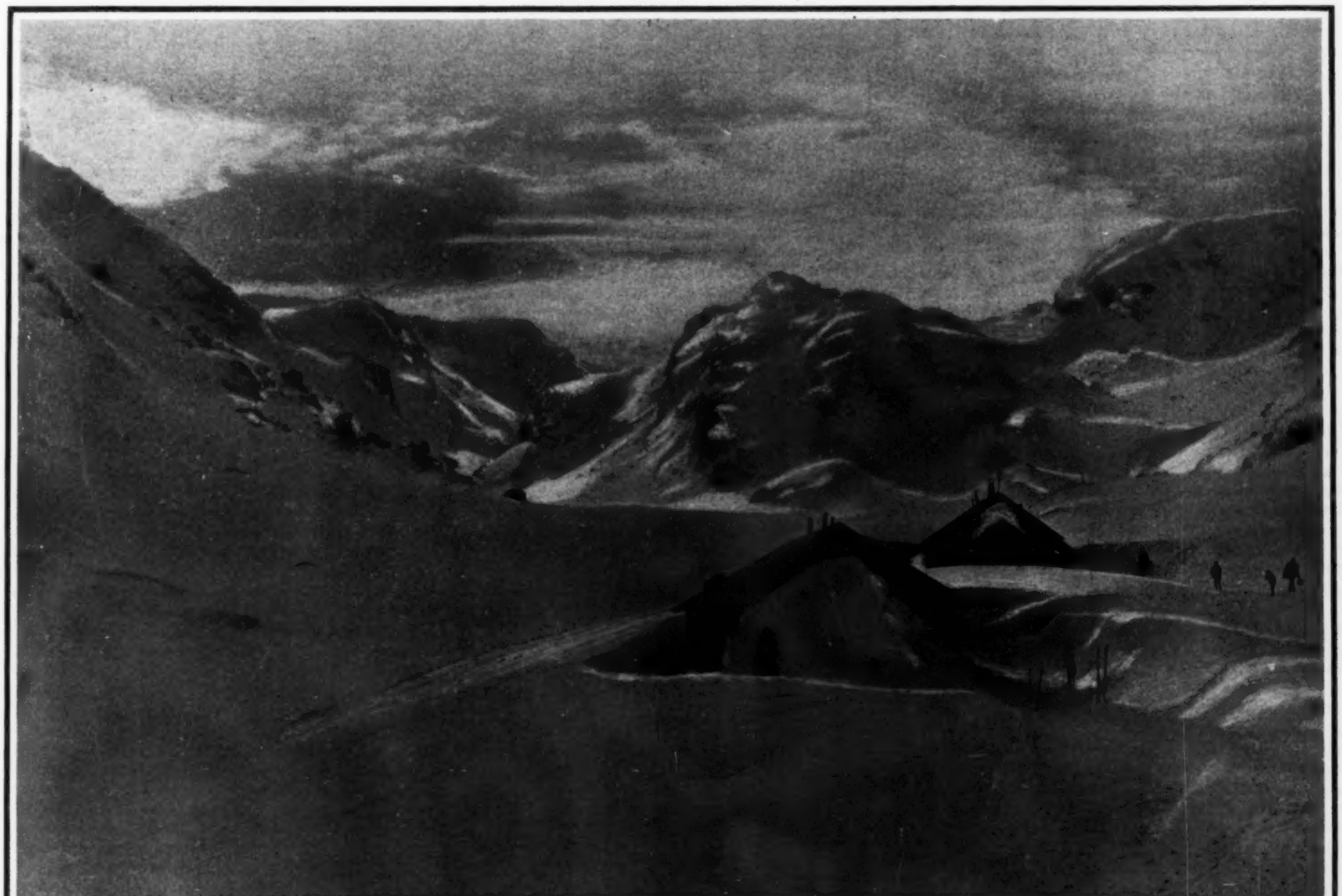
THE FLAAMS VALLEY THROUGH WHICH THE BERGEN RAILWAY RUNS, SHOWING DEFILE NATURE OF VALLEY

TRAIN EMERGING FROM REINUNGA TUNNEL WITH SNOW SCOOP ON LOCOMOTIVE

MYRDALEN STATION, SHOWING ENTRANCE TO GRAVEHALS TUNNEL, 17,420 FEET LONG

THE BERGEN-CHRISTIANIA RAILWAY

BERGEN RAILWAY NEAR VATNAHALSEN. VIEW SHOWING CHARACTER OF COUNTRY TRAVERSED. THE GRADE IS HIGH ON THE HILLSIDE



WINTER VIEW OF MYRDALEN STATION ON THE BERGEN-CHRISTIANIA RAILWAY

THE BERGEN-CHRISTIANIA RAILWAY

climate was also another deterrent factor in rapid construction.

After issuing from the Gravehals tunnel the line commences another ascent, rising 1,411 feet to gain the summit at Taugevandet, 14 miles beyond Myrdalen. When the line has traversed 1¼ miles east of the Gravehals tunnel, the grade being located high on the mountain side, another long tunnel, the Reinunga, is entered. This is the second most important work of this class on the line system, being 5,217 feet in length and with a continuous grade against eastbound traffic of one per cent for the whole of its length. This tunnel was bored throughout with electric boring machines, the current for which was secured from the power station on the east side of the Gravehals undertaking, where 100 horse-power was set aside for this purpose.

In June, 1898, while work on this section was in progress, the government decided that the line should extend eastward from Taugevandet *via* Gulsvik and Roa, where it was to be linked up with the existing eastern railway system. After leaving Taugevandet the descent immediately commences, and the grade is much easier than that on the western mountain slopes, the total drop between Taugevandet and Haugastol, 23½ miles farther on, being approximately 950 feet. The country is then gently undulating for a short distance, when there comes another sudden descent to Aal at 169 miles from Bergen, at an altitude of about 1,414 feet. On the eastern slopes of the mountains, owing to the valleys being wider, the alignment of the line was appreciably facilitated. The descent still continues until at Bromma, 205 miles east of Bergen, it is at an altitude of about 400 feet.

The grade is gently undulating onwards to Gulsvik, after which is another slight ascent to overcome the foothill range, which is pierced at Haversting, at

keeping it open for traffic. Three American rotary plows are used in winter, and one is always kept ready for service, as it has to be requisitioned on one or more occasions every month during the year, and a heavy snow block in midsummer is by no means a rare occurrence. The provision of the line, however, has reduced the time of transit between Bergen and Christiania from 54 to 14 hours, and is an important highway for traffic. Numerous extensions are already projected with a view to bringing the eastern and the western industrial centers into closer communication.

Expiration of the Bradley Patents and the Manufacture of Aluminium

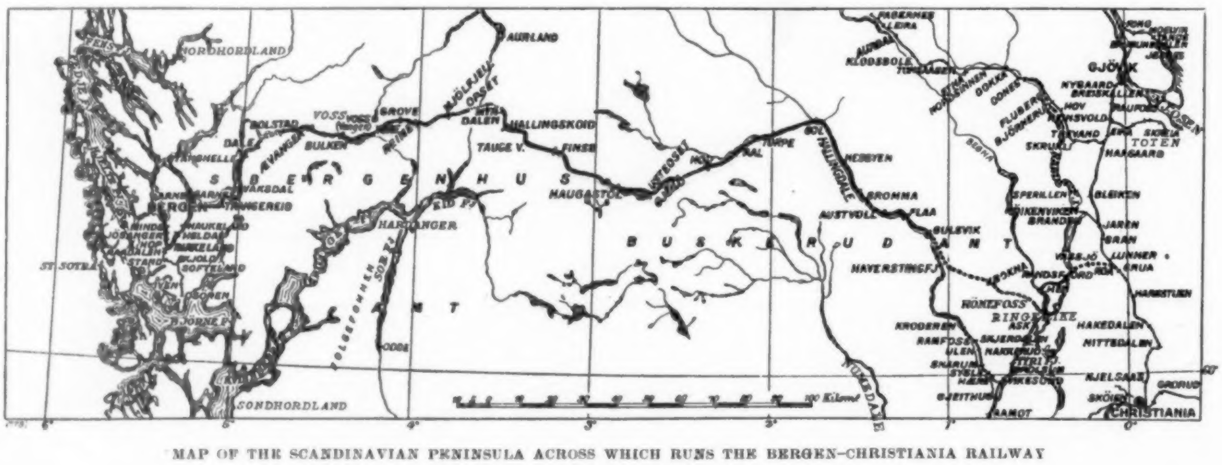
The patents covering the fundamental processes for the electrolytic separation of aluminium as originated by C. M. Hall expired some years back. December 8th, 1908, and February 2nd, 1909, marked the expiration of C. S. Bradley's patents for a continuous process. It is thus, perhaps, an opportune moment to give some attention to the general subject.

Chemical and geological investigations disclose the fact that, so far as the terrestrial crust is concerned, aluminium is the third most abundant substance. Yet aluminium is not cheap. How then is expensiveness to be reconciled with abundance? About 1885 aluminium was worth approximately $12 per pound. The great fact which makes the apparently contradictory one consistent is that aluminium has been exceedingly difficult to isolate from its compounds. But, in combination with other elements, it forms, so it has been calculated, 7.81 per cent of the materials accessible to us. Its price to-day is quite low comparatively to what it has been, so that it is coming into large use in industrial applications.

Aluminium was first isolated in 1827, but its form

steel. This could be lined with carbon. The lining would then, so the inventor states, serve the double purpose of protecting the metal vessel and of acting as one of the electrodes. He suggests the use of the mineral cryolite and of the fluoride of aluminium, in proper proportions, as the proper constituents of the solvent. The aluminium melts and collects in globules on the negative electrode—as the carbon lining—and drops down to the bottom of the crucible. The specific gravity of the metal is quite low (about 2.5 when solid), but that of the bath is lower still.

In carrying out this process of Hall in a commercial manner, perhaps the most noticeable departure has been in connection with the manner of fusing the materials entering into the bath and of maintaining that fused condition. Hall prescribed an external application of heat. He probably thought of no other possibility. But in practice it has been found desirable to supply heat by means of the same current which effects the electrolytic action. A heavy current is needed to perform the double duty. At Niagara Falls the Hall process was early carried out in the following way: Long carbon-lined iron tanks were provided. These constituted the cathodes or negative electrodes. Within these tanks the materials for the bath were placed. Into the bath a row of carbon electrodes depended from a longitudinal support. Thus were secured the positive and negative ends of the circuit. A number of these tanks were connected in series. The aluminium ore used was bauxite, an hydroxide of aluminium employed to furnish the alumina (Al_2O_3) for the bath. Bauxite as found in Georgia and Alabama contains in the neighborhood of 65 or 70 per cent of alumina. In the electrolytic action which takes place, the aluminium melts and drops down to the bottom of the tank; the oxygen set free from the alumina, it has been said, attacks the carbon of the anodes and forms carbon



MAP OF THE SCANDINAVIAN PENINSULA ACROSS WHICH RUNS THE BERGEN–CHRISTIANIA RAILWAY

THE BERGEN-CHRISTIANIA RAILWAY

an altitude of 460 feet, by a tunnel 7,644 feet in length, which owing to the hardness of the rock proved a difficult undertaking, work being carried out first on time, then by contract, and finally by piece work in order to accelerate progress. Issuing from the tunnel, the descent is effected with easy grades to mile 262½, when another sharp climb becomes necessary from 300 feet to 1,000 feet, through Vassjö, and an immediate equally steep descent into Roa, where a junction with the eastern railway system leading into Christiania is effected. The total length of the line from Bergen to the capital is approximately 306 miles.

Altogether there are no less than 184 tunnels on the line, representing a total length of about 24 miles. The constructional work entailed the excavation of nearly 35,500,000 cubic feet of earth and 28,000,000 cubic feet of rock on the high mountain section, while the consumption of dynamite for blasting ran into 1,540,000 pounds. There are 55 stations between the two terminal points, and owing to the later extension of the line eastward from Voss being of standard gage, that between Voss and Bergen had to be altered from the meter gage to secure uniformity. In addition to the tunnels there are fourteen large bridges, the largest three of which are in masonry, one having a span of 150 feet and another being 566 feet in length with eight 70-foot spans. Owing to the exposed nature of the line in the upper sections above the timber line, extensive fencing as a defense against drifting snow was necessary beside the track, these screens being almost continuous for 60 miles between Mjolfjeld and Gjeilo. The line passes through a wilder stretch of country than any other European railway. The winter lasts nine months, and sometimes longer, the snowfall is heavy, and the rainstorms terrific with a tremendous downpour. The line cost about $15,600,000 to build, and the difficulties of construction are only equaled by those experienced in

was then only that of a powder, and this powder could not at that time be melted into a coherent mass. Indeed, it was not quite pure. A quarter of a century later (1854) Deville succeeded in obtaining it in a form which could be melted without oxidation. In the early part of 1856, aluminium is said to have been worth about $90 per pound; but by autumn it had suffered a decline of 70 per cent. Three years later the price was about $12 per pound. At this point it remained until about 1886. In 1887 it fell to $8; in 1888, to $4.84. The following year, when Hall's fundamental patents were issued, the price tumbled to $2. During recent years it has been merely a fraction of a dollar. Up to about 1856 there had been produced a total of perhaps something over a hundred pounds. At present it is manufactured in thousands of tons annually. In nature, aluminium occurs as a more or less pure oxide in the form of corundum, sapphire, ruby, and emery. But the ores from which it is now commercially obtained are chiefly bauxite and cryolite.

While still in his twenties, Hall sought and found a method by which aluminium could be obtained electrolytically. In the successful application of electrolysis, use is made not of an aqueous solution of the aluminium, but of an anhydrous one. He found that a bath consisting of a mixture of a fluoride of aluminium and of a metal more electro-positive than aluminium (as sodium, etc.) would, when at a sufficiently high temperature, dissolve the oxide of aluminium (alumina). Two electrodes are now introduced into this heated mass, and an electric current of proper electromotive force is started. At the positive electrode, oxygen will be given off; at the negative electrode, aluminium is released. Now, it will readily be understood that, in practically carrying out this procedure, it would be necessary to maintain the heat of the bath. Hall's patent (No. 400,766) specifies the use of a suitable furnace. The vessel containing the bath might be of iron or

monoxide. The chemical equation for this reaction is

$$Al_2O_3 + 3C = 2Al + 3CO$$

As this gas rises to the surface of the heated bath, it burns to carbon dioxide. The formation of the carbon monoxide (CO) at the anodes involves the consumption of carbon at that point. So it was found necessary to lower the line of anodes into the bath as time went on.

The ore which Bradley seems to have had particularly in mind was cryolite, the double fluoride of aluminium and sodium found on the coast of Greenland. However, the Greenland ore contains only about 13 per cent of aluminium. Its use is attended with the disengagement of an impure fluoride gas. With bauxite, on the contrary, the disengaged or resulting gas is only carbon dioxide, which may be discharged into the open without ill effects.

One may wonder why it has seemed desirable to get away from the use of external heating. It was found that action on the crucible both from within and from without resulted in rapid deterioration.

The modification of the original process of Hall which eliminated the external method of heating the bath seems to have been due to C. S. Bradley. The broader of his two patents appears to be No. 468,148, which was issued February 2nd, 1892. Let us consider the process as here disclosed. In a pile of the materials in pulverized form, from which the aluminium is to be electrolytically derived, a cavity is made at the summit. To begin operations, two electrodes are first brought into contact, a suitable current having been turned on and an arc formed. The electrodes with the arc between them are now pushed down into the heap. The materials in the immediate vicinity of the arc are fused. Since the fused material forms a fair conductor, the arc now ceases. But the fused condition is maintained because of the electrical resistance to the passage of the current. The aluminium is set free at the negative electrode, and drops to the bottom of

the fused mass. Fresh material is added as the process goes on. There is here no tank at all, the unfused portion of the material serving the purpose. However, this material may be confined in a holder protected by the unfused material. Again, the pile of material may be placed on a carbon slab, which together with a small carbon forms the negative electrode. To begin operations, the arc is developed between the large and small carbons, as before. When the action has proceeded far enough to provide a fused mass between the slab and the positive electrode, the small carbon may be withdrawn.

Scientific Error and Gas Engine Design

Necessary Reversals of Former Engineering Opinion

Rapid as has been the development of the internal combustion engine in comparison with that of other prime movers, it is worth considering whether progress might not have been even faster had it not been for certain widespread misconceptions as to its scientific basis. The history—short as it is—of the internal combustion engine contains several instances in which for a period of some years the most powerful authorities on the subject were urging the acceptance of incorrect theories and were drawing quite wrong deductions from the practical observations they made. As it is proverbially easy to be wise after the event, so it is now easy to see the many grave errors and mistakes that were made, and to realize, in addition, how with a slightly fuller consideration of the matter they could have been avoided.

The two chief directions in which a reversal in the generally received opinion has been found necessary are those briefly denoted by the terms "stratification" and "gaseous specific heats." The former of these unfortunate misconceptions had a great influence on the development of the gas engine. The idea underlying it was introduced by the German engineer Otto in the year 1876 when he patented his famous engine. His idea was to increase efficiency so that the then very high rate of gas consumption should be reduced to a more economic figure, and that the noise and vibration due to the running of such plant, which was so undesirable a feature of its operation, should be minimized. To bring this about he altered the way in which the charges of air and gas were admitted to the cylinder. His plan was first to admit air, then a poor mixture, and finally a rich one. Furthermore, he was careful to keep in the cylinder a portion of the burnt products of the previous explosion. This, he claimed, had the effect of arranging in layers—or "stratifying"—the different kinds of gases and gaseous mixtures. Next to the cylinder there was to be a layer of burnt products, then a layer of pure air, then a layer of a weak mixture, and finally a layer of mixture of full strength. This laminated mixture was to be ignited at its richest point, and the flame was to proceed from layer to layer; this, it was argued, would have two benefits—the provision of a cushion or buffer between the explosion and the piston, and the lengthening of the time of combustion to a period approaching that of the whole stroke. In point of fact, these deductions were not correct. The charge, as it comes into a gas engine cylinder, does not stratify, and any part of the gaseous substance would act—or fail to act—as a "buffer" equally well. Indeed, the way in which combustion proceeded throughout the cylinder was not different—in any material way, at any rate—from that customary with the gas engines which preceded the Otto patent. Although this was so, Otto produced an engine which was a great improvement on any of its predecessors, and this undoubtedly influenced those who listened to his arguments. Even men like Slaby, Dewar, and Bramwell supported his case when the fight over the patents had to be faced, and largely as a result of their support the Otto patent was enabled to rule the gas engine industry for fourteen years. Once it lapsed, all manufacturers eagerly adopted it. From this misunderstanding of the principles of the operation of the engine there issued the temporary creation of a monopoly, and the consequent compulsion on all other manufacturers to use their ingenuities in the manufacture of less efficient models. This error in a proper understanding of the principles of operation greatly hindered the development of the engine.

Had it been realized in 1876 that the real merit of Otto's engine was its mechanical perfection, coupled with the adoption of "compression," the patent could scarcely have been upheld, since Beau de Rochas in 1862 had filed a patent laying down in the clearest terms the ideal direction in which gas engines should be developed, and had placed great emphasis on the necessity for compressing the charge before igniting it. Not only this, but in the previous year, 1861, Gustave Schmidt, in a paper read before the Institution of German Engineers, had advocated compression; it seems, in fact, that the idea was much in the air, and was seizing the imagination of many workers. Nevertheless, from 1862 to 1876 no engines were made to work on this principle, and the great move forward was left to Otto. Although Otto adopted this method, he attributed its success to more novel reasons than compression; the matter thus became the subject of a patent, and others were forbidden to enter the field. Otto's idea that combustion continued throughout the stroke stood its ground for a very long time, despite all that students of the subject of combustion could say to the contrary. Indeed, it may be said to have some life still, though of a not very vigorous kind. It is possible that in special cases combustion may be delayed by the existence of "pockets" in the cylinder or by skin effects, but it is doubtful whether such delay occurs at all in normal circumstances. This is, however, one of the points under investigation at the hands of the Gaseous Explosions Committee of the British Association, which was appointed at the Leicester meeting to report upon this and other allied matters. Mention of the work of the committee brings us naturally to the consideration of the other of the great fallacies which have blocked the path of progress in the gas engine industry, and which the committee has done much to clear up. The amount of this "blocking" is different both in kind and in degree to that due to the stratification fallacy. It has not had the effect of creating a temporary monopoly, but it has deprived the gas engine designer of the scientific guidance to which he is entitled to look. It is as though a traveler in a little-known country should find all the sign posts turned through an angle, sometimes large and sometimes small, but always unknown. A wise traveler in such circumstances would probably pay no attention at all to any of them, and this is very much what the gas engine builders have done. They ceased to believe that the theory of thermodynamics was going to be of any use in the practical work of engine design. The temptation to adopt this attitude became the greater as manufacturers realized earlier than the scientists that there was something wrong with gas engine thermodynamics. The common scientific theory taught that gas engines were ideally capable of a much greater increase in thermal efficiency than the manufacturers knew to be possible. The reason for this discrepancy was that the scientists worked out efficiencies on the basis of constant specific heats, whereas the manufacturers worked with a real substance and not with a "dream stuff." Theorists taught that the amount of heat contained in the gaseous products in a gas engine was exactly proportional to its temperature, whereas, in point of fact, the amount of heat—reckoned from 100 deg. C.—instead of exactly doubling between temperatures of 1,000 deg. and 1,900 deg. C. was really nearer the ratio of 2½ to 1. The difference between 2 and 2½ in these calculations, as in most others, is very great, and renders the old theory inapplicable. The suggestion from the scientific side that there was something wrong with the basis of the old theory came from France, where two eminent physicists, MM. Mallard and Le Chatelier, measured the specific heat of different gases at various temperatures, and found a very marked difference in the values for high and for low temperatures.

This idea was not at first received with much cordiality in England, and even now the accuracy of the French figures is doubted; still there has been a great shift in the point of view, and the Gaseous Explosions Committee, which contains representatives of all schools, has admitted the reality of the French physicists' suggestion as beyond doubt, although declining to commit itself to actual figures pending the result of certain experiments now being undertaken, notably by Mr. Dugald Clerk and by Prof. Hopkinson. The committee has, however, given in one of its reports a curve of specific heat, which is considered to be accurate within 5 per cent. It is not difficult to show by the use of such a curve that a gas engine which was previously thought to be capable ideally of 54 per cent efficiency is really only capable of about 43 per cent when the real nature of the actual working medium is taken into account, as naturally it should be. This is only one instance, but the principle applies to all engines. It cannot, therefore, be thought surprising that gas engine manufacturers should have looked somewhat askance on gas engine thermodynamics. Had this grave misconception as to the nature of specific heats not arisen, there can be little doubt that the designer would have been able to benefit materially by scientific guidance in a way which the circumstances described made impossible. In spite of all difficulties, however, gas engines are now built for the market which achieve thermal efficiency as high as 80 per cent of the theoretically attainable limit for the cycle upon which they work. And it will be interesting to learn, later on, the corresponding percentage of Mr. Humphrey's ingenious gas pump, which works on a different cycle to that of most gas engines, and should have a higher range of efficiencies within its horizon.

As an instance, not of the effect of prevalence of error, but of a condition of entire ignorance, we may refer to the recent work of the Gaseous Explosions Committee in the direction of radiation. No one had suspected previously that gaseous radiation played the important part it does in gas engines, particularly in those which operate at high temperatures. Indeed, it has yet to be definitely settled whether the glowing gas is very transparent, as Prof. Hopkinson says, or merely fairly transparent, as Prof. Callender says, to its own radiation; in the former case the phenomenon is volumetric, and in the latter it would be partly a surface and partly a volume effect. It is now beyond doubt, however, that the amount of this radiation rises with extreme rapidity once the temperature exceeds a certain amount, and this accounts for an important fraction of the considerable heat loss at such temperatures, so providing a hitherto unsuspected reason for keeping the temperatures as low as practicable. With a rich charge and a high compression it is not easy, however, to keep the temperature low, unless on the cycle followed by the Diesel engine where the fuel is admitted by easy stages instead of all at once.

To recapitulate, the error of "stratification" was the means whereby a partial monopoly to manufacture was secured, and it prevented the best men not already working for the Otto people from developing their own engines on the lines along which useful progress alone was possible. The error in gaseous specific heats, which still remains in many books on the subject, has put the manufacturer out of sympathy with scientific work, as he felt he "knew better." The existence of this error is now realized, but it must be a few years before the new experimental work of the physicists has been sufficiently scrutinized and verified to enable science to venture to give a responsible lead to those who, as manufacturers, have for so long had to depend on themselves.—*The Engineer.*

The Mixing of Concrete

The question as to how much water should be used in mixing concrete has often come up for discussion among engineers in Europe, and opinions seem to be divided in this regard. The German Concrete Association has been giving this matter its attention for some time past, apropos of the standardizing of concrete testing methods. In order to elucidate this point, tests were made by preparing concrete in two different places and by different workmen. A great number of samples were then prepared having an aggregate weight of nearly 100 tons. During a period of five years these men put through a series of tests as to resistance to various strains. These experiments are now completed and the results have been published. Among other results the work carried out at the testing laboratory of the Stuttgart Technical School with samples made at the laboratory itself by the same workmen and under the same conditions, showed that for a proper composition of concrete the maximum strength appears to be obtained by using the smallest possible amount of water compatible with the production of a good mixed concrete.

However, the use of the minimum amount of water requires the greatest care and can only be practised by very skillful workmen. Otherwise it is to be feared that the concrete will not be homogeneous. The conclusion is drawn that in proportion as the workmen are less skilled, greater security is given by increasing the amount of water. It is also to be noted that other factors enter in here such as the variable humidity of the sand, gravel, etc., variations in the hygrometric state and temperature, and others, and that these also have an influence on the amount of water needed.

Relics of the Spanish Armada

How a Treasure Ship was Located at Tobermory Bay

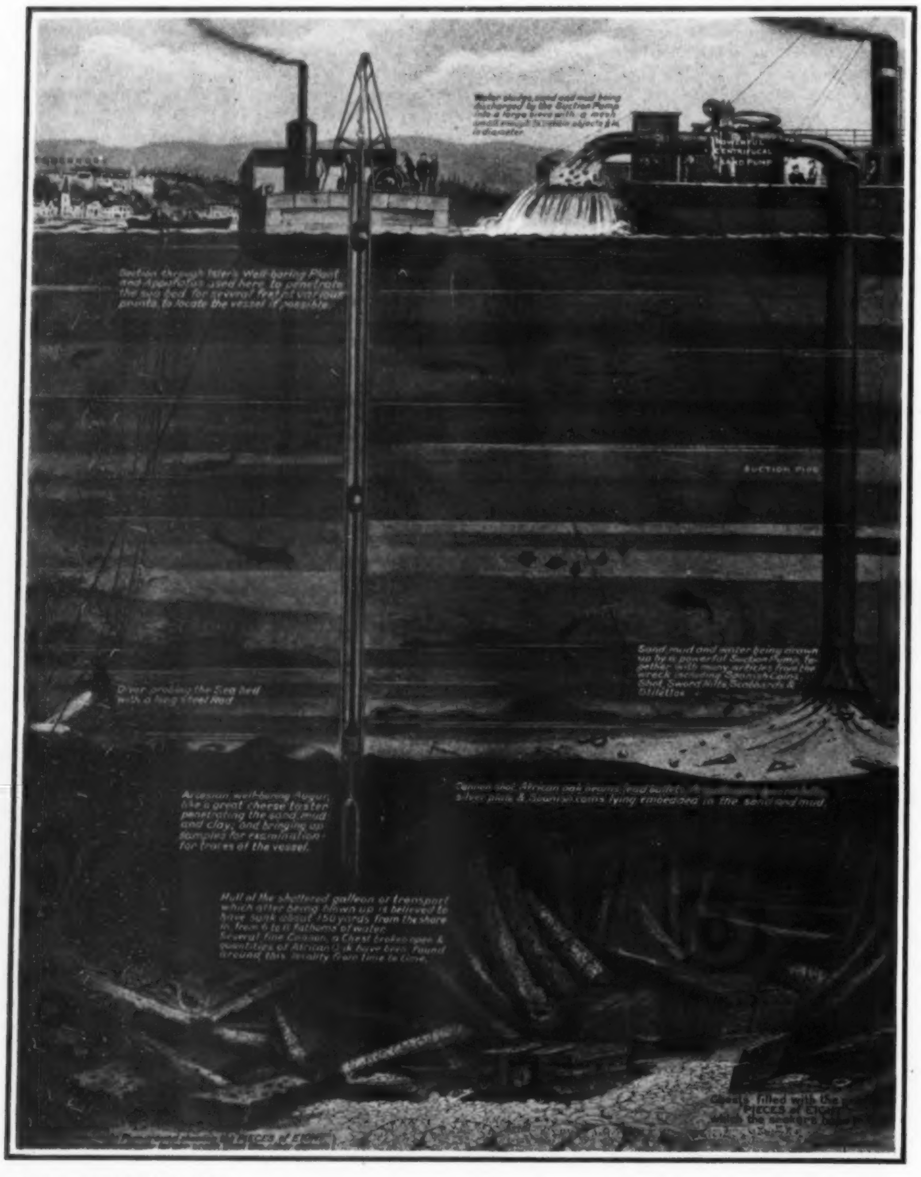
After keeping them securely hidden from human eyes for three hundred and twenty-two years, the waters of Tobermory Bay, off the coast of the island of Mull, England, have at last given up some of their treasures, in the form of a motley collection of battered and worn relics of no value except to historians and antiquarians, but to them of priceless worth, as they tell the story of the tragic end of the famous Spanish Armada, better and more graphically than could pages of histories.

Capt. Burns, the principal wreck officer of the Glasgow Salvage Association, who was in charge of the operations, was untiring in his efforts in bringing these woful remnants of the once splendid "Invincible Armada" to light again. They were recently placed on exhibition at the Glasgow East End Industrial Exhibition, where they attracted the greatest attention.

As tangible trophies of deep romantic interest, these exhibits clearly prove that tradition did not lie when it said that on the spot where the relics were found by Capt. Burns, there was blown up in August, 1588, one of the richest of the ill-fated ships.

It was with the permission of the Duke of Argyll that Capt. Burns pursued his investigations; for, since the wreck of this particular vessel was given into the possession of a Marquis of Argyll by royal grant scarcely half a century after the Spanish squadron met its fate off the coast of England and Scotland, the title of that noble family to the ownership of whatever the waters of Tobermory Bay held of the vessel of the Don, has been undisputed.

The tradition of this particular bit of the stormy history of England has scarcely changed in a single point, in spite of having been handed down from father to son for three centuries, and the recent discovery of the relics has only added to its authenticity. The name of the vessel which was blown up has been spoken of as the "Florida" in old records, but it was really the "Florencia," a Florentine galleon which came from the Levant, one of the Italian possessions of the King of Spain, and was commanded by one Pereija.



By courtesy of the London Graphic.

THE SEARCH FOR SUNKEN TREASURE AT TOBERMORY. HOW THE SPANISH ARMADA SHIP WAS LOCATED AT BOTTOM OF THE BAY

The search for the Spanish Armada ship which sank in Tobermory Bay, Isle of Mull, in the autumn of 1588. The vessel, which has now been located, is believed to be the "Florencia," one of the Italian contingent in the Spanish Armada, which is said to have carried thirty million pieces-of-eight on board. A number of these coins have already been recovered, together with large quantities of black African oak, stone and iron shot, lead bullets, sword-hilts, scabbards, muskets, and stilettos. The "Pieces-of-Eight" Syndicata, which is conducting the search for the sunken treasure, has carried on operations since August, 1910, with divers, a borer similar to that used for sinking artesian wells, and a powerful suction plant, all of which may be seen at work in the engraving.

By far the fullest account in Scottish history of the loss of this ill-fated ship is to be found in the records of Clan MacLean, whom it most closely concerned. In the year 1588 the chief of the House of Duard was Sir Lauchlane MacLean, who had at that period seriously embroiled himself with his neighbors of the Clanranald and the Clan Ian in numerous bloody feuds, and as a result of these had been "denounced rebel" by King James.

Soon after this the "Florencia," commanded by Capt. Don Pereija, was forced by stress of weather and want of provisions into Tobermory Bay. The captain sent peremptory orders to Sir Lauchlane MacLean to supply his ship with such provisions as he might require or as the island could afford. No reply having been made, he threatened to use the means within his power to enforce his request. The haughty chief of MacLean replied to the effect that "the wants of the distressed stranger should be attended to after he had been taught a lesson of more courteous behavior; and in order that he might have such a lesson as speedily as his wants seemed pressing, he was invited to land and supply his wants by the forcible means threatened; for it was not the custom with the chief of MacLean to pay ready attention to the wants of a threatening beggar."

The Spanish commander very discreetly decided to decline the invitation, and now promised payment for whatever necessaries in the way of food and clothing might be supplied him. Finally a sort of friendship sprang up between the Don and his Highland host, and in return for the provisions supplied him, he offered Sir Lauchlane the assistance of a hundred of his marines, and with this help the Scot proceeded to make war on his neighbors. He first ravaged the islands of Rum and Eig, then held by the Clanranald, and the islands of Canna and Muck, the property of the Clan Ian. After devastating these, he made a descent upon the mainland of Ardnamurchan, and, still with his Spanish contingent, laid siege to MacIan's castle of Mingarry.

In a word, he swept through the neighborhood with fire and sword, working havoc wherever he went.

While he was engaged in this way he received a message from Capt. Pereija requesting that the Spanish soldiers be sent back at once, as he was preparing for sea. At the same time he heard that the provisions supplied to the Spaniard had not been paid for. Sir Lauchlane remonstrated with the Don for his injustice, and full satisfaction was promised. On the strength of this the men were sent back, but MacLean, not relying entirely on the captain's promise, retained three of the soldiers as hostages till the debt should be paid. At the same time he sent one of his own men, Donald Glas MacLean, on board the "Florencia" to receive an adjustment of the demands of his people. The emissary was at once disarmed and made prisoner, and no communication was allowed between himself and his friends. But Donald Glas conceived a plan, which, though it meant certain death to himself, promised a speedy and terrible retribution to his captors.

Finding that the cabin in which he was confined was close to the magazine, he found an opportunity to force his way into it, and laying a train from it to the outside, he fired it, and the ship was blown to pieces, killing the three or four hundred on board.

The wreck of this vessel and the enormous treasure which she was reported to contain created a great deal of interest in the spot where she had sunk. They early excited the interest of the Argyll family, and in 1611 the Marquis of Argyll obtained as a gift from Charles I. the vessel, provided he paid to the Duke of Lennox and Richmond the one-hundredth part of the ship, after the deduction of expenses. In 1665 the Earl of Argyll entered into a contract with one James Mauld, wherein the latter agrees to give the former one-fifth part of all that shall be recovered from the ship of the Armada, lost beside Tobermory. These contracts have gone on and on, but no great store of gold and silver has been found, nothing more in coin than a few pieces now and then, though some fine brass cannon have been found.

Among the articles recovered, apart from old timber, warped ironwork, stone and iron cannon balls, human bones and skulls, and silver coins, there is also a bronze breech-loading gun 4½ feet in length, one of the fifty-six carried by the "Florencia."

The gun is still in such a condition that, although it lay in twelve fathoms of water for more than three centuries, the monogram of the maker, supposed to have been Benvenuto Cellini, and the date, 1563, are still visible. The ball with which the gun was loaded still remained in it. The breech action is lifted out of the gun by a handle similar to a laundry smoothing iron.

A projection fits into the bore, and the wedge-shaped hole at the side of the gun has apparently been used to fasten the breech-block and prevent it from being forced back by the firing of the charge. When the breeck-block was removed, it was found not to be solid but to have been used as the powder chamber. The iron bullet was found in direct contact with the powder, and in front of it were the remains of a wad of rough fiber, apparently manila oakum. The bore of the gun is one and five-eighths inches. A round hole at the end was for use in ramming and cleaning out the gun between the shots. This gun, therefore, takes its place among the earliest known

breech-loading guns. The bronze of which it has been made was not affected by the water.

The broken blade of a sword, a pistol, and a hook and tackle, thickly incrusted with limestone, have also been found, as well as a piece of the woodwork of the ship in a fossilized condition.

The tradition is that the "Florencia" had fifty-six guns on board, and thirty million pieces-of-eight. The latter still repose beneath the sand and mud of the bay, making their recovery very difficult even by the methods at present in operation, which are shown in the illustration.

The Destruction of Weeds by Chemical Means—II*

An Important Agricultural Problem

By Harold C. Long, B.Sc., Author of "Common Weeds of the Farm and Garden"

Concluded from Supplement No. 1831, page 77

IN the course of his investigations Bolley observed: (1) That succulent plants and those of slow growth are more easily killed than others; (2) that flower parts and parts of plants covered with "bloom" or waxy coatings are more or less protected; (3) that plants possessed of hairy surfaces are, as a rule, more easily killed than those with a smooth surface; (4) that chemicals act differently upon plants of different families, even though the plants be wetted equally readily—charlock and dandelions, for example, are readily attacked by copper sulphate solution, while creeping thistle, wild buckwheat and clover are slowly attacked; and (5) that most of the chemicals readily destroy the tissues of any plant where the surface is broken.

It was found that charlock could be sprayed with absolute success; that king-head or greater rag-weed (*Ambrosia trifida*) could be sprayed in much the same way as charlock and with considerable success at certain times, success depending on the age of the weed; that creeping thistle (*Cnicus arvensis*) was most effectively sprayed with sodium arsenite (one and a half to two pounds per fifty-two gallons of water) and common salt (one-half barrel per fifty-two gallons of water); that succulent portions of the stem and leaves were destroyed when the plants were

FIG. 10.—Garden Nightshade (*Solanum nigrum* L.) A Pest of Arable Land and Gardens, and Poisonous to an Extent Which Varies According to Conditions.

a foot high and seeding was prevented; that spraying of dandelions on lawns and fields with sulphate of iron was a marked success; and that the perennial sow-thistle (*Sonchus arvensis*) was practically unaffected by sprays. (It may be remarked that this weed, only too common in Britain, is quite smooth and covered with bloom.)

Bolley concluded that the following weeds may be eradicated or largely subdued in grain fields by the use of chemical sprays: False flax (*Camelina sativa*), worm-seed mustard, tumbling mustard, common wild mustard (charlock), shepherd's purse, pepper-grass, ball mustard, corn cockle, chickweed, dandelion, creeping thistle, bindweed, plantain, rough pigweed, king-head, Red-River weed, rag-weed cocklebur. The following were found not to be effectively controlled by chemical sprays as now used: Hare's-ear mustard, penny cress, pink cockle, perennial sow thistle, lamb's quarters, pigeon grass, wild oats, chess (*Bromus secalinus*) couch grass, sweet grass, and wild barley.

A large number of tests with the sulphates of iron and copper were carried out some years ago by Dr. A. B. Frank in Germany.[1] Thirty-five species of weeds were involved. Clover was but little damaged by a 15 per cent solution of iron sulphate (seventy gallons per acre, and one hundred and sixty gallons per acre), or a 5 per cent solution of copper sulphate, the clover soon recovering after losing its first leaves. In addition to charlock, the following plants were more or less damaged by sulphate of iron: Corn cockle, poppy, sow thistle, corn flower,

FIG. 11.—Corn Buttercup (*Ranunculus arvensis* L.) × 1. Often Very Troublesome in Corn Fields on all Soils, Especially on Chalk. Often Termed "Watch Wheels" From the Flat Spiny Fruits.

field thistle, dandelion, groundsel; and the following were more or less damaged by a 5 per cent solution of copper sulphate (seventy gallons per acre): spurrey, groundsel, black bindweed. Though these plants appear to be rarely destroyed they are prevented from producing flowers and seed.

In experiments conducted in 1903 at the Holmes Chapel College of Agriculture and Horticulture, "clover was untouched" when the covering oat crop was sprayed with one hundred gallons of a 4 per cent copper sulphate solution. In 1899 a 4 per cent solution of the sulphate (one acre) completely killed *Polygonum Persicaria*, but clover was uninjured. A 4 per cent solution of copper sulphate (fifty gallons per acre) was also used to destroy charlock in mangolds, the latter being uninjured.

Experiments at the Agricultural Experiment Station of the University of Wisconsin showed[2] that a

FIG. 12.—Shepherd's Needle, Venus's Comb (*Scandix Pecten-Veneris* L.) × 1. An Annual Corn-field Weed Sometimes Extremely Troublesome on Light and Chalk Soils.

20 per cent solution of iron sulphate (fifty-two gallons per acre) did not injure cereals, clover seedlings or lucerne, but cockle-bur, ragweed, dandelions, daisies, wild lettuce, and several common farm weeds were partly eradicated. Sow thistles and creeping thistle were not effectively sprayed, and it was concluded that their eradication by spraying is not practical for the average farmer.

In demonstrations conducted throughout Ontario, the effect of copper sulphate was observed in relation to twenty-eight weeds,[3] and while charlock was the only species readily destroyed, it was found that the flowers of field bindweed and white cockle, and the leaves of creeping thistle, sow thistle, blue weed (*Echium vulgare*), and bull thistle (*Cnicus lanceolatus*), were very sensitive to the spray, and largely destroyed.

At the Yorkshire College, Leeds, experiments showed[4] that clovers were practically uninjured when sprayed with a 12 per cent solution of sulphate of iron, while peas, beans, carrots, onions, beet, and parsnips were but slightly damaged, and this was

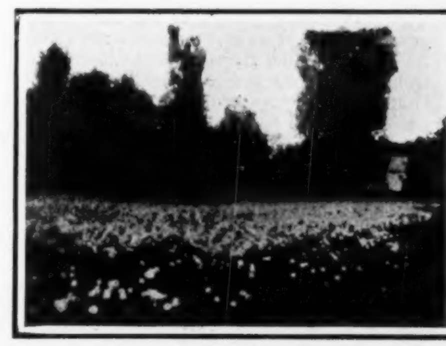


FIG. 13.—A Plot of Lawn Upon the North Dakota Agricultural College Campus Infested by Dandelions Untreated Before Blossoming Time. Left Continuation of Fig. 14.

FIG. 14.—A Plot of Lawn Upon the North Dakota Agricultural College Campus Infested by Dandelions of the Same Strength of Growth as Those Shown in Fig. 13, but Treated With Iron Sulphate Solution Thrown by a Traction Sprayer Two Weeks Before Blossoming Time. Compare With Fig. 13. These Two Photographs Show in a Striking Manner the Effects of Spraying.

the case also with swedes, turnips and mangolds.

Spurrey (*Spergula arvensis*) has been found to be checked by spraying with a 3 per cent solution of sulphate of copper (forty gallons per acre), flowering and seeding being checked.[5] In another trial[6] the results were held to show that a 5 per cent solution of copper sulphate (fifty gallons per acre) may be relied on to kill spurrey.

At the Woburn Experimental Farm it has been shown by pot trials that the common poppy (*Papaver Rhoeas*) is much injured by a 2 per cent solution of copper sulphate; when the solution was applied to both surfaces of the leaves these "turned brown, became shriveled, and to a great extent the plant was killed, for the seeding was almost entirely prevented, the flower heads withering completely." It has also

* *Knowledge.*

[1] Bekämpfung d. Landw. Unkräuter durch Metallsälze.—Arb. aus. der Biol. Abth. für Land. und Fortsw., I. Bd., 1900.

[2] Bulletin No. 179, 1909.

[3] Ann. Report, Dept. Agric., Ontario, 1904, Vol. I., p. 39.

[4] Report on the Spraying of Charlock and Runch, 1899.

[5] Rept. on Expts., Midland Agric. and Dairy Inst., 1900.

[6] Univ. Coll. of North Wales, Bangor, Bull. ii., 1908.

been stated that the common scarlet poppy is very sensitive to a 13 to 20 per cent solution of iron sulphate. At the Woburn Station also experiment showed that the wild onion (*Allium vineale*) may be destroyed or at least largely reduced by spraying with a 5 per cent solution of pure carbolic acid.

Dr. Hiltner found that dodder on clover may be destroyed by spraying with a 15 per cent solution of sulphate of iron, so applied that it hits both the plants and the surface soil with some force. The clover was blackened at first and appeared to be ruined, but sprouted strongly afterwards.

Sulphate of iron has been found to destroy charlock if applied in the powdered conditions when the dew is on the leaf, three to four hundredweights per acre being necessary. This is considered by M. Hitier to be more easy of application than in the form of a solution, and more practical on small areas.

Calcium cyanamide has also been found useful for destroying charlock in corn crops.

The action of gasoline on certain plants has been observed at the Woburn Experimental Fruit Farm, and it was noted that the poppy, teasel and wild strawberry were practically killed.

The efficacy of carbon bi-sulphide in killing large tropical "weeds" has lately been discussed by E. V. Wilcox in a press bulletin issued from the Hawaii Agricultural Experiment Station, and plants appear to be destroyed owing to the freezing effect.

The results of experiments at the Vermont Agricultural Experiment Station and elsewhere are summarized in Farmer's Bulletin, No. 124, of the United States Department of Agriculture—and salt, carbolic acid, liver of sulphur, kerosene, copper sulphate, arsenate of soda, and so on, are dealt with.

The foregoing notes show conclusively that in one way or another many weeds may be attacked by means of solutions of chemical preparations, with good prospects of preventing seeding or of destroying the plants altogether. It is, however, still desirable that exhaustive experiments should be conducted on a co-operative basis in different parts of Great Britain, for the effects of the various solutions vary with the plant sprayed, the local meteorological conditions, and the thoroughness with which the work is carried out. With the results of such experiments placed clearly before them, farmers would have some definite information on which to proceed.

Correspondence

Screw Propeller Design

To the Editor of Scientific American Supplement:

Starting with the indisputable fact that any length, width, and shape of a propeller blade, provided it be given a positive angle, will develop more or less thrust, one is forced to the conclusion that the theoretical true-screw principle of construction is not a necessary factor in producing propulsion. Further, it being a matter of record that a propeller with "straight-pitch," that is, with blade angles not varying from hub to tip, thus defying most theories of propeller construction, developed more effective thrust than a scientifically designed and perfectly constructed "screw-pitch" propeller, in actual competition (Lougheed, "Vehicles of the Air," p. 241), I am convinced that progress requires the rejection of the screw propeller theory, which, after centuries of application (dating from Leonardo da Vinci, 1452-1519) still remains, even in the minds of experts (?), a mystery. So that to-day the manufacture of screw propellers continues to be a mere experiment or tentative effort toward "maximum efficiency," an effort which is just as likely to be equaled, offhand, by any schoolboy with the medium of two shingles tacked to the ends of a broomstick.

I advance the idea, and claim that every screw propeller—so called—works or advances by the effect of its rotation through the air, not as a result of its pitch angle or angles, causing helical travel, but as a result of reaction of the air pressure against the compression side of the blades, causing straight-ahead travel; and that its rate of advance in feet per second is nothing more nor less than the terminal velocity of a surface equal to the entire area of the propeller's circle of revolution, impelled by said reaction pressure, against the air pressure resulting from, and retarding, the progressional velocity of said surface. In other words, a propeller is a parachute "falling" horizontally. The reaction, or thrust, in the one case, taking the place of the aeronaut's weight in the last. (This is an extreme example, cited merely to illustrate the idea. In the following paragraphs I will show that efficiency in a propeller will result in great part from the proper relation of its blade widths to rotational velocity, whereby the "face" it presents will be the least possible percentage of the total area of its circle of revolution.)

This view is supported by the following experiment: "Fix a thin blade, say one inch wide and one foot long, with its plane exactly midway and at right angles to the end of a rod. On thrusting this through a body of water, or immersing it in a stream running in the direction of the axis of the rod, the resistance will be simply that caused by the water against the mere superficies of the blade. Next put the rod and blade in rapid rotation. The retarding effect against direct motion will now be increased near ten-fold, and is equal to that due to the entire area of the circle of revolution. By trying the effect of blades of various widths, it will be found that, for the purpose of effecting the maximum resistance, the more rapidly the rod revolves, the narrower may be the blades. There is a specific ratio between the width of the blade and its velocity. This experiment, though referring to the action of surfaces in water, is yet exactly analogous to the conditions obtaining in air." (Wenham, Aeronautical Annual, 185, p. 90.)

Further support of this idea is afforded by the fact, commonly experienced, that a propeller which in a ground test gives from 100 to 300 pounds thrust, when applied to an aeroplane and given an air test, will render as little as 25 per cent, and from this figure up to perhaps 30 per cent its ground efficiency. The aviator wonders why, and "customary thought" answers, "slip." Again: "An advantage of the propeller in affording the starting impulse—of an aeroplane—is that its thrust is highest when the vehicle speed is lowest." Now, really, why? According to my reasoning, because the thrust as measured in the ground test is the actual thrust (or reaction) value, acting against the posterior face of the propeller disk, and when the air test is made (and the thrust apparently drops through the effect of slip) what really happens is that the thrust maintains its intensity, but the propeller's actual progressional velocity is less than what "screw theory" demands, because at said velocity the air pressure acting against the anterior face of the propeller disk equals and balances said thrust. Again quoting the parachute simile, the propeller has reached its "terminal velocity."

Now, this reasoning explains why a straight-pitch fan blower is of little value as a propeller, because its blade tips are so wide, usually, as to lose efficiency as regards reaction pressures, through the phenomena of "interference." And this width of blade multiplied by the number of revolutions per second results in the formation of a solid disk opposed to progression.

Conversely, the narrow tips and blade widths of Curtiss's straight-pitch propeller, which "defied most theories of propeller construction," but proved more efficient than a scientifically designed "Chauviere" propeller, gained that efficiency because its long narrow blades were of the best shape to obtain reaction pressures from the air, and their width multiplied by the number of revolutions per second resulted in a total area less—by perhaps 50 per cent—than the total area of their circle of revolution, thus reaching their terminal velocity at a comparatively high speed, in terms of miles per hour.

This reasoning also explains the cause of the greater comparative efficiency of propellers of great diameter, turning slowly. The peripheral speed of the blade tips obtains great reaction pressures, and the low number of revolutions per second do not nearly close the area of the propeller disk, thus letting the air from in front pass between the blades.

A very recent patent has been granted an English inventor for a propeller having perforated blades, for which great efficiency is claimed.

Need I cite more instances? No. Apply my reasoning to any type of existing propeller, true-screw, straight-pitch, or "mongrel." What has been mystery in regard to their action becomes plain by means of the simplest arithmetical calculations. Conversely, following this idea, a propeller can be designed for any duty required, with much greater certainty of success than by the hit-or-miss system now in vogue.

Los Angeles, Cal. Joseph A. Blondin.

Effects of Forests on Climate

To the Editor of Scientific American Supplement:

I was very much interested in an article appearing in the Scientific American for October 29th, 1910, subject, "Forests in Relation to Climate and Floods." The most of us readers will agree with Mr. Moore when he states that deforestation has no perceptible effect on precipitation. His figures and arguments are, as to that fact, conclusive. However, we take exception to his deductions with regard to the run-off of water from denuded tracts.

We choose to regard only those facts which have to do with conditions in this country. Our reason is that deductions, not figures, were given for statements with regard to floods in Europe. As far as these facts are concerned, we could glean the great fact that floods are not on the increase in Europe, the continent which has perfected the system of forest conservation.

Turning to the facts with regard to our own country, two stand out prominently: 1. Ground cultivated to a depth of eight inches is a better conserver of rainfall than the primeval forest humus. 2. In the Cumberland, Tennessee, and Ohio rivers, the number of flood days has decreased from 2,100 in 1871-1889 to 1,400 in 1890-1908. Either Mr. Moore's general deductions are based on other figures, or the deductions based on the above figures are obscure to us.

1. No figures are given as to the percentage of denuded forest land that is put under cultivation. To an observer of the tracts cut off by our western lumber companies, it would seem that very little is ever touched by the plow. Usually timber is on the slopes of hills that cannot be and seldom are cultivated. Where cultivation does occur, I have yet to see the ground that is ever tilled to a depth of eight inches. This county, in the midst of reserves, is as large as New Jersey, but seldom do the ranchers plow deeper than six inches; the majority are satisfied with scratching the surface. So it is all over our western mountains. We would all admit Mr. Moore's first point if he could show that the greater part of denuded land is cultivated, and this to a depth of even six inches.

2. As to the second point. The mean annual stage of the Ohio varies as the rainfall—that is evident. The relative number of flood days is striking: 2,100 in the earlier period, 1,400 in the later period of equal length. Now, it appears at once that in late years, 1,400 flood days have sufficed to carry off an amount of water formerly carried off during 2,100 flood days, the mean stages of the two periods indicating that approximately the same amount of water was carried in each period. It would seem that the floods were more intensified in later years while they lasted, but that they were not of such long duration. Ohio newspapers seem to bear out this fact annually when the freshets occur. Evidently the run-off in the upper reaches of the Ohio has been occurring more rapidly in late years.

We believe that this question is vital enough to ask for a more extended report from Mr. Moore. A diagram showing high and low stages, with their durations, would get at the crux of the matter. Again, are the people of the headwaters of the Ohio ceasing to cultivate their farms? We do not reflect on Mr. Moore's deductions; we believe that he has figures that will more definitely substantiate his conclusions. May we have them? We are open to conviction.

Yampa, Colo. Fritz Taeusch.

White Cement

Colored surfaces or objects in cement are made by adding pigment to the surface layer, but the natural color of the cement must be taken into account in selecting and apportioning the coloring matter. For this reason numerous attempts have been made to produce a white cement. Often colored cements are made by adding suitable metallic oxides before the furnace process. Ordinary Portland cement takes its hue from the color of the substances entering into the raw material, such as iron and manganese compounds. Nearly all the clays and marls contain such oxides, so that it is difficult to have a white cement. Dr. Wormser overcomes the difficulty by a process in which he obtained white cement from ordinary clays and even ferruginous clays. The crude mass is mixed with 2 to 5 per cent of sal ammoniac and during the furnacing process this is volatilized and escapes in the shape of fumes. It may be recovered by passing the fumes through scrubbers in which the sal ammoniac (ammonium chloride) is absorbed by the water. Chloride of iron also passes in the fumes. The furnaces should be of the small vertical type and this increases the cost of production, but on the other hand the product brings a higher price. If an absolutely white cement is not needed, a more economical process is to use chloride of zinc for treating. The resulting product always retains a small amount of this salt and it has a slight greenish tint.

Coloring Soft Solderings.—To impart, to a copper soldering, the copper color, first prepare a saturated solution of pure blue vitriol; this is applied to the soldered place. On passing over the soldering with an iron or steel wire, it will be coated with a covering of copper, which can be thickened as desired by repeated application of the blue vitriol solution and touching with the wire. To impart a yellow color to the soldered spot, prepare a mixture of 1 part of saturated white (zinc) vitriol solution and 2 parts of blue vitriol solution; apply this to the soldered spot and rub with a zinc rod. If we desire to gild the spot, the place coppered is coated with gum or fish sound solution and dusted with bronze powder. As soon as the gum is dry, we can, as in other cases, obtain a bright surface, by burnishing.

INDEX OF INVENTIONS

For which Letters Patent of the United States were Issued for the Week Ending January 31, 1911

AND EACH BEARING THAT DATE

[See note at end of list about copies of these patents]

Adding machine, Thompson & Newton 982,901
Adding machine, J. G. Vincent 983,009
Aerial machine, J. Humphris 983,233
Aeroplane, S. S. Yarrington 983,192
Airship, C. E. Lamburth 983,243, 983,244
Ambulance, I. H. Russell 982,997
Amusement device, aerial, R. Hartwig 983,049
Animal catching and holding device, R. A. Morris 983,248
Animal trap, J. H. Tharp 983,181
Atomizer, J. S. Thurman 982,903
Automobile attachment, C. R. West 983,103
Axle, vehicle, N. L. Ballance 983,112
Axle, vehicle wheel, K. Voller 983,186
Baling press, A. R. Stahl 982,891
Basin holder, sanitary bed, W. C. Johnson 982,965
Beater, rotary, Emmott & Mercer 982,942
Bed spring support, T. Hauser 982,959
Bedstead, R. & F. Cane 982,934
Belt, chain driving, J. E. Dukelow 982,802
Berry box, folding, W. W. Wood 982,919
Billiard cue, C. Winning 983,189
Billing device, G. C. Shepherd 983,090
Binder, loose leaf, E. Thompson 983,007
Boiler safety device, steam, J. P. Jurgensen 983,144
Book and record binder, bill, O. C. Manteufel 982,842
Book, file index, D. F. Maher 983,072
Bottle cap remover, A. W. Stephens 982,893
Bottle, essence, F. W. Jones 982,966
Bottle, non-refillable, G. Kollenborn 982,969
Bottle stopper, J. M. Creighton 983,211
Box folding machine, E. W. Labombarde, reissue 13,198
Box or case for containing goods for transport, A. J. Warne-Browne 983,099
Box shooks, treating, M. J. Miller 982,973
Briquets for metallurgical or other purposes, manufacture of, W. F. Collins 982,796
Broom corn holder, J. R. Douglass 982,941
Broom corn press, J. J. Faucher 983,128
Buckle, hip strap, A. F. Hoska 982,963
Bulletin, F. De Silva 982,940
Bung-making machine, M. Moul 982,980
Burglar trap, Werrick & Dailey 982,911
Cabinet, kitchen, A. Abolt 982,777
Cabinet, portable nail and screw holding, F. A. Billstone 983,116
Camera, M. Niell 982,849
Camera focusing device, A. S. Grant 983,047
Camera shutter, J. C. Dassler 983,027
Can. See Insulated can.
Can flanging and heading machine, L. C. Sharp 983,002
Can opener, W. B. Miller 983,160
Candle and shade holder, S. O. Elting 983,126
Car antifriction side bearing, railway, J. F. O'Connor 983,080
Car coupling, H. W. Sanford 982,999
Car door, W. L. Blennerhassett 982,787
Car dumping mechanism, J. H. Baisden, Jr. 983,110
Car mover, E. T. McBride 983,154
Car replacer, F. B. Plasko 983,166
Car safety attachment, W. C. D. Body 983,022
Car safety brake, street, C. E. Gierding 983,041
Cars and other receptacles, discharging doors for dumping, W. L. Coughtry 983,026
Carbureter, H. A. Miller 983,247
Carrier system, W. Aab 982,920
Cash indicator and register, F. C. Osborn 982,853
Cash register, electric, J. P. Cleal 982,938
Cash register operating mechanism, T. Carroll 982,936
Caster, H. J. Horwich 982,820
Caster, furniture, N. S. Covey 983,210
Catalytic synthesis of methane, Bedford & Williams 983,199
Cement and making same, B. Bruhn 983,024
Cement, manufacturing, C. von Forell 982,945
Chalk holder, F. L. Dethloff 983,215
Check protector, A. E. Ayer 982,782
Chemical engine, J. T. Thomas 983,006
Chocolate, preparing emulsified, S. T. Achor 982,779
Chocolate product, emulsified, S. T. Achor 983,014
Christmas tree stand, W. Poppendieck 982,866
Clamp, Krumbaar & Maiboeuf 983,148
Clamping mechanism, head, C. L. Grohmann 983,225
Cleaning and polishing device, A. Johnson 982,824
Clock, H. C. Ebrick 982,804
Cock or faucet, H. Mueller 982,981
Coffee beans, cleaning and refining, J. Thum 982,902
Coffee purifier, G. Richie 982,877
Coffee urn, L. S. Flatau 983,130
Coin deliverer, A. Sandvik 983,088
Coke ovens, gas burner for, R. Muller 982,983
Collar, lock front turn over, O. H. Keep 982,827
Comb. See Dressing comb.
Compressor, rotary, Vinzent & Bell 983,010
Concrete structures, interior mold or form for, F. S. Graef 983,046
Conveyer, traveling, R. M. Clark 983,205
Cooker, thermo electric, R. S. Kirkpatrick 982,831
Cork, treatment of, M. Grunzweig 982,950
Corn cutter, H. Buchner 983,202
Corn hanger, seed, C. F. Phipps 982,864
Course and distance finder, G. H. Burrage 982,793
Covers on receptacles, machine for clamping, L. Blumenthal 983,117
Crushing machine, J. E. Symons 982,899
Cultivator, J. R. West 982,912
Cultivator, J. M. Allen 982,921
Current conductor, J. Regenstreif 982,873
Cut-off, variable, R. Eaton 983,222
Dampening the seams of folded collars, machine for, L. R. Heim 983,051
Dental apparatus, T. E. Bridger 982,931
Dental napkin, A. L. Simpson 983,174
Digging machine attachment, ditch, W. Arps 982,781
Dish pan draining attachment, I. A. Wallquist 982,908
Display rack, J. M. Hendrix 983,052
Display rack for scythes, H. Carver 983,203
Doll, rag, C. Sackman 982,880
Door locking device, emergency exit, H. G. Voight 983,011
Door securer, R. O. Hammond 983,136
Drawbridge locking device, R. M. Agnew 983,194
Dressing comb, G. L. Winn 982,918
Drying machine, W. McNaught 983,076
Drilling machine, hydraulic rotary, A. G. Heggem 983,050
Dye, azo, O. Gunther et al., 982,952, 982,953, 982,955
Dyestuff, azo, O. Gunther et al 982,954
Dyestuff for chrome mordanted wool, monoazo, Geldermann & Oster 983,132
Dynamo brush holder, O. Hohme 983,230
Dynamo mounting, J. F. McElroy 983,158
Earmark, H. C. Stoll 982,896
Electric apparatus, C. A. Lohr 983,245
Electric conductor, E. Morss 983,151
Electric conductor connector, W. L. Bliss 983,258
Electric cut-off, Sturgeon & Shanley 983,178
Electric furnaces with polyphase currents, supplying, P. Girod 983,043
Electric lighting system, F. W. Reeves 982,872
Electric machine, dynamo, Behrend & Field 982,784
Electric machine, dynamo, C. J. Fechheimer 982,806
Electric machine, dynamo, A. M. Gray 982,811
Electric machine, dynamo, D. Hall 982,813
Electric machine, dynamo, A. Kingsbury 982,830
Electric regulation, J. L. Creveling 982,800
Electric signal system, F. B. Wood 983,191
Electric switch, W. T. Pringle 982,869
Electric time switch, automatic, B. F. Flegel 983,224
Electric wall box, Murray & MacDougal 983,162
Electrode, storage battery, P. J. Kamperdyk 983,062
Elevator safety device, A. Nemeth 983,079
End gate and lifting jack, O. Bucklin 982,792
End gate attachment, F. M. Carney 983,121
Engine driving mechanism, beating, S. R. Wagg 983,187
Engine starter, internal combustion, C. I. Sackrider 983,168
Engine steering mechanism, road, G. A. Anderson 983,197
Engines in self propelled vehicles, starter for explosion, D. B. Gardner 982,946
Engines, safety starting crank for explosive, P. Swenson 982,898
Extension pipe, H. P. Ley et al 982,836
Eyeglass mounting, J. M. Chappel 983,204
Eyeglasses, F. W. Nolte 982,985
Fastening, A. L. Creger 982,790
Faucet bung, D. Beebe 983,019
Faucet strainer, H. Mueller 982,982
Filaments, films, and other cellulose products from cellulose solutions, manufacture of, R. Homberg 983,139
File leaf or holder for sales slips, etc., Zimmer & Benjamin 983,106
Filing machine, E. C. Bruil 982,791
Fire detector, automatic, Hughes & Hoffmann 982,822
Fireproof shutters, baffle for, J. G. Wilson 983,104
Fishing reel, I. D. Wright 983,013
Fishing spoon, W. A. L. Miller 982,974
Floor and ceiling plate, A. J. Beaton 983,115
Flue cleaner for stoves and ranges, W. Jaques 983,143
Flue cutting device, L. B. Burt 982,932
Fluid pressure governor, M. J. Weber 983,101
Force, means for neutralizing, A. B. Jones 983,237
Forging of wheels of iron or steel, mechanical, J. Giriot 983,042
Freight lowering and hoisting apparatus, J. L. Sauters 982,881
Gaff, W. F. Werline 983,102
Game apparatus, A. H. Porter 983,250
Garbage closet, C. S. Robinson 983,087
Gas burner controller, A. Girtanner 982,808
Gas engine, variable horse-power, A. M. Leoni 983,150
Gas generator, acetylene, E. Hayne 982,961
Gas generator, acetylene, A. Henney 982,962
Gas generators, automatic regulator for acetylene, C. C. Wakefield 983,255
Gas heater, J. Rubado 982,879
Gas taps from a distance, device for opening and closing, B. C. H. Pegler 982,861
Gases or vapors to the action of liquids, apparatus for subjecting, W. Feld 983,037
Gate, T. A. Hill 983,229
Gear, Geneva, J. B. Reimund 982,874
Gearing controlling means, transmission, C. W. Parker 983,249
Gearing, shift transmission, H. C. Dreisvogt 983,217
Gearing, transmission, C. W. Parker 982,856
Gearing, transmission, A. J. Morse 982,978
Gearings, clutch mechanism for transmission, C. W. Parker 982,855
Generating apparatus, Reeve & Noyes 982,871
Glass and gasket cutter, circular, J. B. Shuttleworth 983,173
Governor and reversing gear, automatic, C. J. Pilliod 982,988
Governor, engine, J. McGowan 983,159
Grader, road, J. B. Fender 982,944
Grain drier, W. J. Applegate 983,198
Grease gun, S. P. Townsend 983,095
Grinding machine, B. M. W. Hanson 983,226
Grinding mill, M. J. Davidsen 983,028
Grubbing frame, R. H. Fisher 983,129
Hacksaw, C. B. Chandler 982,937
Hair curling device, D. Marinsky 983,074
Hame fastener, N. J. Rogers 982,995
Hammer, magazine, Durst & Nabors 983,221
Handcuff, F. Busch 982,933
Handle attachment, W. P. Patrick 983,082
Harrow, J. C. Eubank 983,035
Harvester, corn, J. C. Corderman 982,798
Hat body clipping machine, E. W. Barnum 982,926
Hat pins and the like, protector for, A. Kemish 982,829
Hem, extensible, W. C. Rowland 982,878
Hinge, gravity, A. N. Anderson 983,015
Hoeing machine, rotary, G. Konig 983,242
Hoist, automatic, G. C. Grabie 982,800
Hook and eye, J. L. Poalk 983,167
Horse groomer's gearing, G. F. Press 982,868
Hose bridge, J. J. Bardon 982,924
Hydrocarbon lighting system, C. K. Harding 983,227
Ice machines, water purifier for, J. J. Schrade 983,160
Ice making system, A. E. Beals 983,017
Igniter with spark emitting mass, J. Kellermann 983,238
Illuminating interiors of buildings, means for, J. J. Jennings 982,823
Incandescent mantle, inverted, C. K. Harding 982,958
Indicating device, C. N. Wisner 983,190
Insulated can, F. W. Niebling 982,848
Insulator protector, J. E. Field 983,039
Internal combustion engine, M. T. Anderson 983,100
Internal combustion engine, D. Clerk 983,206
Internal combustion steam motor, E. P. Noyes 982,850
Invalid lifting apparatus, J. Fravel 982,807
Iron. See Soldering iron.
Ironer, sleeve, waist, and cap, S. McLaughlin 983,246
Ironing machine, M. Achenbach et al 982,778
Jar closure, vacuum, W. J. Peelle 982,890
Kinematographic apparatus, A. Mallet 983,073
Labeling apparatus, receptacle, C. F. Jenkins 983,060
Labeling machine, can, W. R. McDonald 983,157
Ladder, Dahill & Bartlett 983,213
Ladder, adjustable, A. A. Sheetz 983,172
Ladder, extension, J. R. Spears 982,890
Ladder, folding, E. R. Walters 983,188
Ladder raising and lowering machine, E. F. Dahill 983,212
Lamp for automobiles or other vehicles, E. D. Dunning 982,803
Lamp, inverted incandescent mantle, R. E. Bruckner 982,790
Lamp lighting apparatus, E. Barber 983,113
Lamp support, dirigible, F. Jackson 983,234
Lantern, C. Orgaard 982,852
Last, H. F. Loewer 982,838
Lead pigment and making the same, A. S. Ramage 982,992
Leather, making sole, J. A. Tanner 983,005
Lever mechanism, controlling, C. W. Parker 982,857
Life preserver for aviators, A. C. Ulmer 982,907
Linotype machines, cold lock for, A. W. Le Boeuf 982,834
Liquid fuel burner, J. B. Hayden 982,960
Loading and unloading device, R. L. Morgan 982,977
Lock and latch, A. Phillips 982,863
Loom, I. L. Peterson 982,862
Loom stop motion, velvet, J. B. Derfinak 983,030
Looms, glass bar bracket mechanism for, F. Benz, Jr. 983,020
Lubrication apparatus, J. Triftshauser 982,906
Lubricator, N. L. Chalmers 983,025
Lubricator, S. S. Lyon 983,071
Magnetic materials, apparatus for handling, J. F. Schabel 982,883
Magneto electric machine, W. W. Dean 983,029
Mail bag catcher, G. E. Watkins 983,100
Mail box transmitting apparatus, W. E. Stewart 982,894
Marine table, J. A. Bakarcih 983,111
Mattress, adjustable, A. Bores 983,118
Mattress, revetment, C. C. Condie 983,209
Measuring device, liquid, W. B. Jackson 983,058
Meat tenderer, M. Howard 983,056
Metallic hoop or band, S. & T. Svenson 983,093
Milk can, E. H. Humphrey 983,232
Moistener and sealer for envelops, etc., C. R. Stewart 983,004
Moistening device, J. F. Cummins 982,939
Mold making machine, G. A. McKeel 982,971
Motor. See Internal combustion steam motor.
Motor, J. W. Willson 982,917
Motor, W. S. Elliott 983,034
Motor control system, E. W. Stull 982,897
Motor controlling apparatus, electric, G. H. Whittingham 982,913
Motor controlling switch, S. H. Keefer 983,063
Motor regulating device, wind, K. E. Neren 983,163
Music player, electrical, D. J. Hauss 982,814
Music sheets, apparatus for cutting perforated, A. J. Swing 983,094
Musical instruments, tempo indicator for mechanical, G. H. Bent 982,786
Nail driver, M. Dickson 982,891
Nailer, automatic, W. J. Ott 982,854
Necktie, M. A. Griesemer 982,948
Nose bag, J. K. Allshouse 983,108
Nut lock, B. J. Greer 982,947
Nut lock, C. A. Evans 983,036
Ore concentrator, S. K. Behrend 982,785
Ore pulverizer, J. J. Knight 983,067
Packing, metallic, M. Brussard 983,201
Packs on animals, means for lashing, W. T. Moore 982,975
Paper making machine, W. C. Nash 982,845
Paper receptacles, mechanism for making, T. Allatt 982,780
Pen, fountain, F. M. Ashley 982,922
Pen, fountain, M. S. Olsen 983,165
Pens in pockets, device for holding fountain, A. Napolitano 982,984
Perforating machine, A. J. Swing 983,254
Pessary, wire spring stem, G. B. Rowell 982,996
Phonograph, W. W. McCauley 983,155
Phonograph, E. M. Turner 983,183
Photographic apparatus, Hutteballe & Morler 983,141
Piano sounding board, H. Derdeyn 983,125
Piano, violin, J. L. Warner 983,012
Pickax, H. G. M. Kuhn 982,832
Picture machine, moving, G. W. Bingham 983,021
Pictures, machine for producing flickerless moving, L. L. Thurstone 982,904
Pipe attachment, T. Charles 983,122
Pipe coupling, automatic train, J. C. Evans 982,943
Pipe coupling, train, Kelly & Royer 983,239
Piston rod, W. R. McKeen, Jr. 982,972
Plate or pan lifter, S. A. Holman 983,054
Platform or plank, J. S. Tilley 982,905
Plow, L. Carr 982,935
Pocket book, O. T. Porter 983,085
Pool tables, advertising frame for, E. D. Watkins 982,909
Portable drill, J. A. L. Pealing 983,083
Post and means for attaching wires thereto, J. W. Haddon 982,957
Power transmitting mechanism, electro-magnetic, A. J. Bowie, Jr. 982,789
Press. See Baling press.
Press, A. L. Jenkins 983,059
Press, H. C. Dreisvogt 983,218
Primary battery, electric, F. W. Spanutius 983,175
Printing plates and the like, holder for, Owens & Lee 983,081
Printing press, M. A. Droitcour 983,219
Printing press, platen, F. Stedinger 982,892
Pulp press, F. W. Barhoff 982,925
Pump, automatic, C. W. McGonigle 982,843
Pump, centrifugal, J. L. Heald 983,137
Pump rod guide bearing, J. H. Range 982,870
Pump, rotary, A. E. Stoker 982,895
Pump, suction, C. R. Smith 983,253
Pumping outfits, swivel rope socket for wire line, L. C. Sands 982,998
Quilting machine attachment, J. C. Touchstone 983,182
Rail bond, J. A. Jamison 983,235
Rail joint, J. Hudson 982,821
Rail splice, J. Thomas 982,900
Railway chair, S. W. Groah 982,949
Railway, pleasure, J. W. Bourke 983,119
Railway rail anticreeper, S. C. Stickney 983,092
Railway rail splice joint and brace, J. W. Clark 983,123
Railway switch and switch operating device, F. P. Lane 982,833
Railway tie, Pratt & Calahan 982,867
Railway water tanks, attachment for the spouts of, J. L. Lattimer 983,149
Razor stropper, automatic, G. F. Patterson 982,859
Reflector, P. Kieber 983,241
Refrigerating systems, automatic controlling mechanism for, Carpenter & Kimball 982,794
Refrigerator, J. H. Dagg 983,124
Refrigerator, oyster shipping, C. E. Linkie 982,837
Roller press, E. U. G. Reagan 983,086
Rolling metal shapes, apparatus for, E. E. Slick 982,888
Roofs, comb cover for corrugated, Williams & Roth 982,916
Rotary engine, I. M. Kephart 983,257
Rotary motor, W. S. Elliott 983,033
Roundabout, E. B. Rayner 982,993
Ruffling and stitching machine, A. H. De Voe 983,031
Rule, slide, G. W. Richardson 982,876
Sack holder, J. W. Vance 983,185
Sash lock, D. M. Barr 982,783
Sash weights, apparatus for molding seamless, A. S. Hodges 982,817
Sash weights, molding, A. S. Hodges 982,818
Saturating and crushing machine, B. Hosmann 983,065
Saw clamp, E. C. Stearns 983,176
Saw handle, E. B. Olson 982,986
Saw, pneumatic, C. J. Olson 982,851
Sawmill set works, C. W. Willett 982,915
Scale, E. C. Pool 982,865
Scoop for bailing narrow shafts, G. Meyer 983,077
Scraper for road engine wheels, G. A. Anderson 983,196
Scraper, wheel, Kindleberger & Granville 983,065
Seal, bottle, J. A. Rennie 982,875
Seal for faucets, C. C. Hucke 983,140
Seaming the heads upon cans, apparatus for, L. C. Sharp 983,001
Sewing machine embroidering attachment, M. Ackerman 983,193
Sewing machine ruffler, Greist & Beckert 983,048
Shade supporting device, N. Mora 982,976
Shaft coupling, R. Lindner 983,070
Shaft sinking cross head, safety, T. Bryant 983,120
Shaping machines, work holder for, H. E. Morton 982,979
Shelving, J. F. Masters 983,075
Ship manipulating and turning apparatus, F. M. Morten 983,078
Shock absorber, Wilcox & Cuno 982,914
Shocking device, hand, H. Ferris 983,038
Shoe polishing machine, E. F. Hecker 983,138
Show case, knockdown, L. N. Levinsohn 983,151
Sidewalk elevator, extension, F. C. Birch 982,929
Signal. See Warning signal.
Signaling device, electric, D. M. Bliss 982,930
Signaling mechanism, H. McDonald 982,839
Skate brake, roller, S. J. Nesbitt, Sr. 982,846
Slag, apparatus for atomizing liquid, G. Gantzen 982,964
Sleeping bag, E. H. Fitch 983,223
Smoke consumer, A. G. Krieg 982,970
Solder hemmed caps, machine for making, E. M. Cobb 983,208
Soldering iron for soft soldering, H. Schweitzer 982,884
Sound recording and reproducing machines, stylus or needle for, J. Jetter 983,061
Speed gage, O. Evensen 983,127
Speed indicator, A. Trowbridge 983,096
Speed mechanism, variable, H. W. Schatz, 983,251, 983,252
Speed transmission mechanism, J. Barnes 983,016
Stackers, hay retaining device for hay, J. O. McCreery 983,156
Stamp for marking parcels, letters, etc., rotating band, O. Kjeldaas 983,066
Stamp, hand, Lowe & Seger 983,153
Station indicator, B. Kende 983,145
Steam boiler, M. W. Sewall 983,170
Steam boiler, J. R. Vance 983,184
Steps, folding, C. Halstead 983,135
Stirrup, saddle, R. L. Graham 982,810
Stove F. A. Nieberding 982,847
Stove, E. H. Gold 983,044
Stove or heater, liquid fuel, G. P. Wolff 983,105
Stropper, I. W. Irving 983,142
Stump puller, A. T. Fairey 982,805
Suction apparatus, F. Barby 982,923
Swingletree, E. G. Bormann 982,788
Switch box or receptacle, C. C. Maison 982,841
Tannin silver albumen compound, R. Weil 982,910
Tapping device, J. C. Roth et al 983,259
Telegraph system, I. Kitsee 983,240
Telephone desk attachment, C. W. Cochran 982,795
Telephone system F. C. Unger 983,098
Tire, automobile, C. L. Vandervort et al. 983,008
Tire casing, H. R. Holbrook 983,231
Tire, cushion, L. Knapp 982,968
Tobacco pipe, M. Loewenstein 983,152
Toy, A. T. Goldfield 983,133
Toy, A. Coaske 983,207
Toy, aerial, J. Knowles 983,147
Trace holder, safety, J. B. Levy 982,835
Traction wheel, S. M. Bower 983,023
Tractor, J. B. Coffron 983,256
Transporting bodies, approach for moving, E. L. Hocquart 982,816
Trees, vermin and bug shield for, A. M. & R. D. Barry 983,114
Tube mill, P. T. Lindhard 983,068, 983,069
Turbine, Elliott & Faber 983,032
Turbine governing mechanism, F. Hodgkinson 982,819
Typewriting machine, L. Ney 983,164
Typewriting machine ribbon spool, Tanner & Jones 983,180
Typewriting machines, controlling mechanism for the carriages of, J. B. Secor 982,885
Valve, R. L. Hobbs 982,815
Valve actuator for locomotives, emergency slide, F. P. Sasaman 983,089
Valve and oiler, combined throttle, L. C. Bayles 982,927
Valve and valve actuating means, C. J. Siddall 982,887
Valve for hydrocarbon engines, mixing, P. D. Johnston 981,825
Valve for internal combustion engines, mixing, P. D. Johnston 982,826
Valve gear for stationary engines, C. J. Pilliod 982,987
Valve gear, locomotive, H. J. Pilliod, 982,989 to 982,991
Valve grinder, J. Y. Porter, Jr. 983,084
Valve mechanism for internal combustion engines, Drummond & Bostock 983,220
Valve seating machine, J. F. Higbee 983,228
Vehicle, motor, Allen & Conly 983,107
Vehicle spring, M. Tulbovitch 983,097
Vehicle wheel, W. J. Straight 983,177
Vending machine ejector, Grover & Barber 982,812
Vending machine, post card, Gossman & Brucken 983,045
Ventilating apparatus, F. E. Swift 983,179
Vertically adjustable table, F. Schimmel 982,882
Vessel closures, apparatus for applying, J. Conley 982,797
Vise and work holder, universal, Skow & Petersen 983,091
Vise, bench, T. A. Gannoe 983,131
Voting booth, A. E. & R. E. Patterson 982,858
Wall construction, W. H. Dean 983,214
Warning signal, C. F. Jenkins 983,236
Washing machine, A. B. Smith 982,889
Watchmaker's tool, F. W. Bechberger 983,018
Water governor, A. Dickerson 983,216
Water heating apparatus, J. F. Muller 982,844
Water trap, steam actuated, J. E. Jones 982,967
Water tube boiler, Sewall & Jacobus, 983,000, 983,171
Wave motor, T. J. Beaudette 982,928
Weather guard and sash lock, E. S. Kelly 982,968
Well drilling machine, T. H. Kerr 983,064
Wheel. See Traction wheel.
Wheel and band, vehicle, J. N. Rickards 982,994
Wheelbarrow, W. Boszol 983,200
Whip, D. C. Hull 983,057
Whisk broom, Hobart & Scott 983,053
Windmill lubricator, H. H. Macomber 982,840
Window attraction, F. M. Kennedy 983,146
Wrench, F. H. Servatius 982,886
Wrench, G. W. Gruver 982,951
Wrench, Hachmann & McFee 982,956
Yarn cleaner, Garey & Lowman 983,040

A printed copy of the specification and drawing of any patent in the foregoing list, or any patent in print issued since October 4th, 1859, will be furnished from this office for 10 cents, provided the name and number of the patent desired and the date be given. Address Munn & Co., Inc., 361 Broadway, New York.

Canadian patents may now be obtained by the inventors for any of the inventions named in the foregoing list. For terms and further particulars address Munn & Co., Inc., 361 Broadway, New York.

Snow Blindness

IN May, 1883, the explorer Jochelson, traveling alone by sledge in Northern Siberia, was overtaken by a snow storm that proved to be literally "blinding." He slept during part of his enforced halt of twenty-four hours, and on awakening he found himself totally blind, in an uninhabited region which he was traversing for the first time. There was only one hope. He knew that the sledge was headed southward. He drove his team of nine dogs in the opposite direction, as nearly as he could judge, and after a long journey in subjective darkness, though the sun was shining on the fresh snow, he reached the place where he had parted company with his Tungus guides, a few days previously. The dogs recognized the spot and stopped. But the place was deserted, so it was necessary to go on—how far, the blind man knew not. Again the dogs stopped and pawed the ground, and a sound of distant yelping indicated the presence of foxes in a burrow directly beneath the sledge. While the blind explorer was trying to straighten the reins which the excited dogs had tangled, the team escaped and ran away with the sledge, carrying the provisions and water. Jochelson, blind and destitute, wandered about in the snow for several days until he reached a pile of stones which, he conjectured, had been employed to anchor a native tent.

Under the stones he found a pool of water with which he slaked his thirst, but he was so weak that he lay down to die. He was rescued five days later.

Hygieia, the organ of the Dresden Hygienic Exhibition, which recalls this interesting story, adds that the natives of the Arctic regions have learned how to protect themselves from snow blindness by means which will be exhibited at Dresden next summer. The natives of Alaska use richly ornamented wooden eye-shades. Some other Eskimo tribes used to wear wooden spectacles, provided with narrow slits, but nowadays the apertures are usually larger and are covered with bits of colored glass obtained from European visitors. Arctic explorers and Alpine tourists usually protect their eyes with dark glasses.

Rats and Plague

By G. F. Petrie

Although the recent epidemics of bubonic plague in China, India, and other parts of the world have been always associated with outbreaks of the same disease among rats, the historical study of plague throughout the world reveals the singular fact that previous to 1800 very few references to a coincident mortality among rats have been put on record. Many excellent accounts of the older outbreaks, notably of the Black Death in Europe in 1347, and the Great Plague of London in 1665, are in existence, but careful research into these documents by modern historiographers—Haeser, Hirsch, Abel, and Sticker—has shown that for reasons difficult to discover very scanty mention of associated rat mortality has been made.

The earliest recorded instance is perhaps that given in the Bible in the account of the pestilence among the Philistines, which they ascribed apparently to "the mice that marred the land." Avicenna refers to the association between rats and plague in his description of the epidemic in Mesopotamia about the year 1000 A. D. Nicephorus Gregoras, writing of the Great Plague of 1348, which entered Europe by way of Constantinople, makes a similar reference. Rats are mentioned in connection with the plague in Yunnan about 1757, and later in 1871-3. In India an association between rats and plague is noted in the *Bhagavata Purana*, by the Emperor Jehangir in the plague epidemic of 1615, and in a report of the Pali plague in Rajputana in 1836. Lastly, Orreus refers definitely to rat mortality in his account of the epidemic of 1771 in Moscow.

The identity of the disease in rats with that affecting man was established by the discovery in 1894 of *B. pestis* by Yersin and Kitasato.

Within the next few years the relationship between rat and human plague was investigated in many parts of the world—by Thompson and Tidswell in Sydney, Clark and Hunter in Hongkong, Snow, Weir, Hankin and James in India, and by Kitasato in Japan. In 1905 the Plague Research Commission was appointed to investigate plague in India, and the reports of this commission represent the results of the most exhaustive inquiry into the subject that has yet been carried out.

The commission early turned its attention to the relationship of rat plague and human plague, and instituted an extensive examination of the rats in Bombay and elsewhere for the presence of plague infection. The maps and charts, representing graphically the results of this examination, clearly show the correlation between the epizootic and the epidemic—the rat epizootic preceding the epidemic by an interval of ten to fourteen days. Every outbreak of bubonic plague, when adequately investigated, was found to be associated with the disease among rats. The conclusion must be drawn that every epidemic of bubonic plague is caused by the concomitant rat plague.

In Bombay the rat population is an enormous one, *Mus decumanus* (the brown or gray rat) swarming in the sewers, gullies, and outhouses in the city, and *Mus rattus* (the black rat) living in countless numbers in the houses of the people. The latter species is of especial importance in plague epidemics, because it is essentially a house rat; it may almost be said to be a domesticated animal. The severity of the epizootics in the two species will be appreciated when it is stated that during one year the examination of 70,789 *M. decumanus*, taken from all parts of Bombay city, proved that 13,277 were plague-infected = 18.8 per cent, and that out of 46,302 *M. rattus* examined 4,38[illegible] were plague-infected = 9.4 per cent. The heavier incidence of plague in *M. decumanus* is explicable by the circumstance that the flea infestation of this species is more than twice that of *M. rattus*.

Some interesting observations on the distribution of different species of rats in India have been made recently by Capt. R. E. Lloyd, I.M.S. The most common rats in India are *M. rattus*, *M. decumanus*, and *Gunomys* (*Nesokia bengalensis*). *M. decumanus* is common both in Bombay and Calcutta, but is absent from the city of Madras. It is significant that Madras is the one port in India which has never been seriously infected with plague. *M. rattus* appears to be universally distributed in India, whereas *M. decumanus* does not seem to occur in India except in seaports. *Nesokia bengalensis* is found in every part of India.

The question of the transportaion of plague by ship rats is an extremely important one, but has not so far been thoroughly worked out. It would appear that *M. decumanus* is the species most commonly infesting ships, although *M. rattus* is also found.

Sticker, in his history of plague epidemics, quotes the statement that *M. decumanus* got into Europe from Persia about the year 1725. In England *M. rattus* was displaced by the invasion of *M. decumanus* about this time. At the present day the predominating species in this country is undoubtedly *M. decumanus*; *M. rattus* is, however, becoming increasingly common in the seaports.

An important question in plague epidemiology is the mode of conveyance of the infective organism from the plague rat to man. It is impossible even to summarize here the numerous experiments and observations on this subject, but it may be said that from many sides, and especially from experiments in the laboratory and in actual plague-infected houses, a mass of evidence has been raised which incriminates and indeed convicts the rat flea as the transmitting agent of the infection.

In India the rat flea, *Loemopsylla cheopis*, which closely resembles the human flea, *Pulex irritans*, in appearance, is by far the most commonly found species. In England the common rat flea is *Ceratophyllus fasciatus*; a single specimen only of *L. cheopis* has been found up to the present time.

L. cheopis, especially if hungry, will bite man; *C. fasciatus* does not take to man with any readiness, but will undoubtedly bite on occasion. This difference in the appetite of the two species for human blood may be of significance in determining the likelihood of the spread of rat plague to human beings.—*Nature*.

Trade Notes and Formulæ

Soft Solder for Metal, Glass, Porcelain, etc.—Pour over granulated zinc, a solution of blue vitriol. Of the solution, 20 to 36 parts are mixed with sulphuric acid of 1.85 specific gravity, and while stirring, 70 parts of quicksilver added, washing out well and cooling. When using, heat the solder to about 707 deg. F. (375 deg. C.).

Weather Foretelling (Barometer) Flowers.—One hundred parts of chloride of cobalt, 10 parts common salt, 50 parts of gelatine, 20 parts glycerine, 200 parts distilled water. The chloride of cobalt is dissolved in the necessary quantity of water, the glycerine added, then in this is dissolved warm the salt and the gelatine, previously softened in cold water. When cooled filter it, and in it soak the flowers, etc., formed from uncolored material.

Cements for Water Pipes.—*a.* Cement lute for cast-iron water pipes: 24 parts Roman cement, 8 parts white lead, 2 parts litharge, 1 part rosin. All to be pulverized and mixed and then worked up into a putty with old linseed oil to which half its weight, in rosin, has been added and which has then been kept at boiling heat until all the rosin is dissolved. *b.* Equal parts of calcined lime, Roman cement, potter's clay and loam, separately well dried, finely ground, mixed and kneaded up with linseed oil. *c.* Rosin and tallow melted together and finely sifted plaster stirred in until the desired consistency is obtained.

TABLE OF CONTENTS.

Page.

I. CHEMISTRY.—The Manufacture and Industrial Application of Ozone.—By Dr. Oscar Linder.—8 illustrations.............. 84
The Destruction of Weeds by Chemical Means.—II.—By Harold C. Long.—5 illustrations.............. 93

II. ELECTRICITY.—Electric Car Lighting.—By D. F. Crawford.... 82
Expiration of the Bradley Patents and the Manufacture of Aluminium.—1 illustration.............. 90

III. ENGINEERING.—The Generation of Power.—By D. S. Jacobus.............. 85
The Bergen-Christiania Railway.—6 illustrations.............. 88
Scientific Error and Gas Engine Design.............. 91
The Mixing of Concrete.............. 91

IV. MISCELLANEOUS.—Relics of the Spanish Armada.—1 illustration.............. 92
Correspondence.............. 94